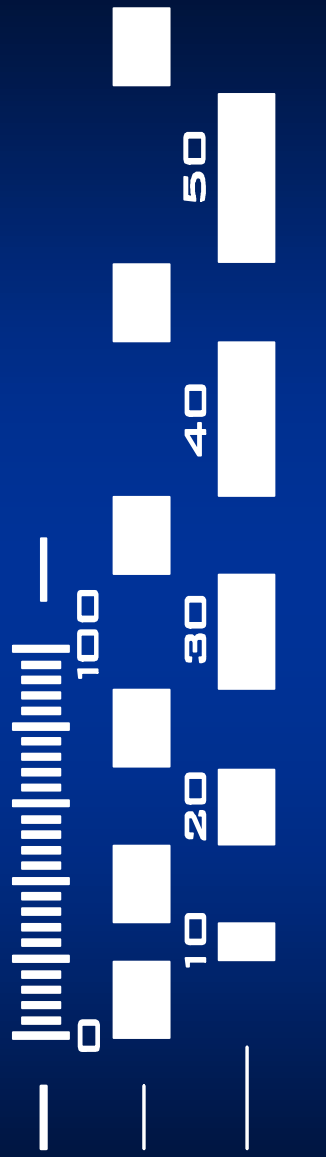
On the measurement of softness

Paul Tomlins, Martin Rides, Crispin Allen
Hugh Gong, Helen Petrie, Steve Lackovic

16 October 2003



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- Kawabata Evaluation System for fabrics
- What is sensory softness?
- Physical
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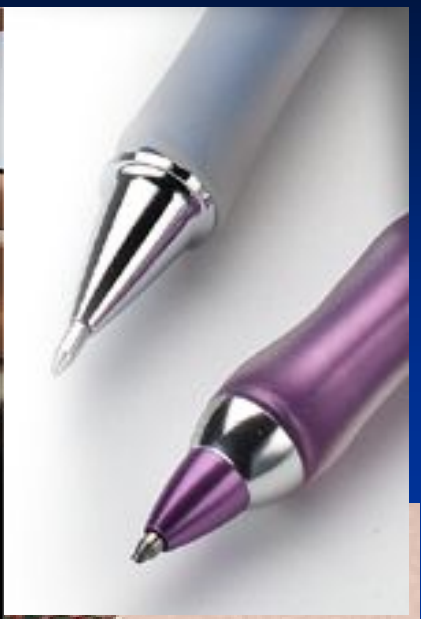
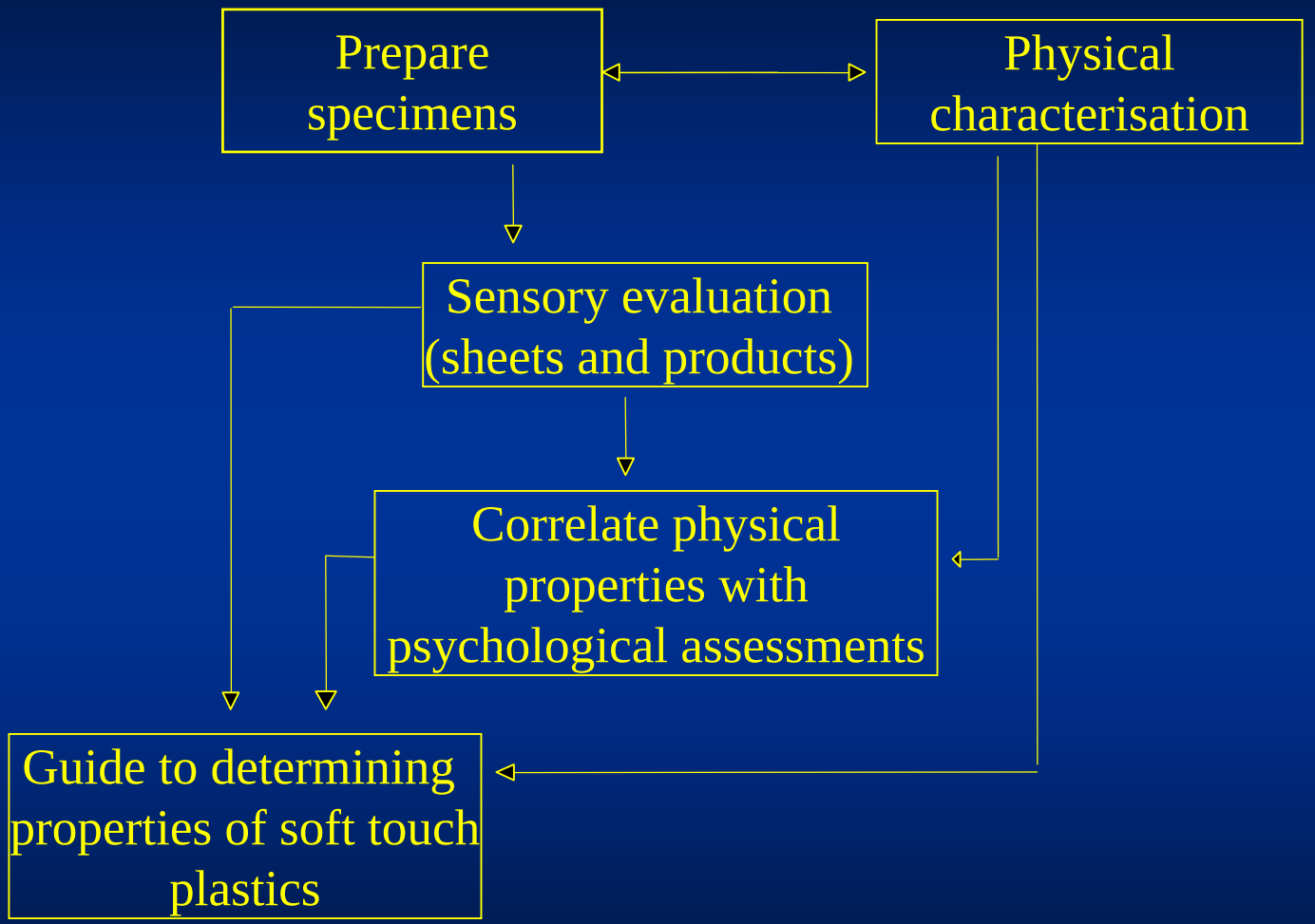
Applications of soft touch plastics



Project overview



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Fabrics: Kawabata Evaluation System (17 parameters):

Physical & mechanical properties:

- Weight
- Surface friction
- Tensile
- Surface roughness
- Shear
- Bending
- Compressive properties
- Thermal conductivity

Sensory panel evaluation

Primary Hand Values:

- Stiffness
- Smoothness
- Fullness and softness

Correlation between calculated hand values and sensory panel evaluation

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Kawabata Evaluation System

Tensile

Bending

Surface roughness

Thermal conductivity

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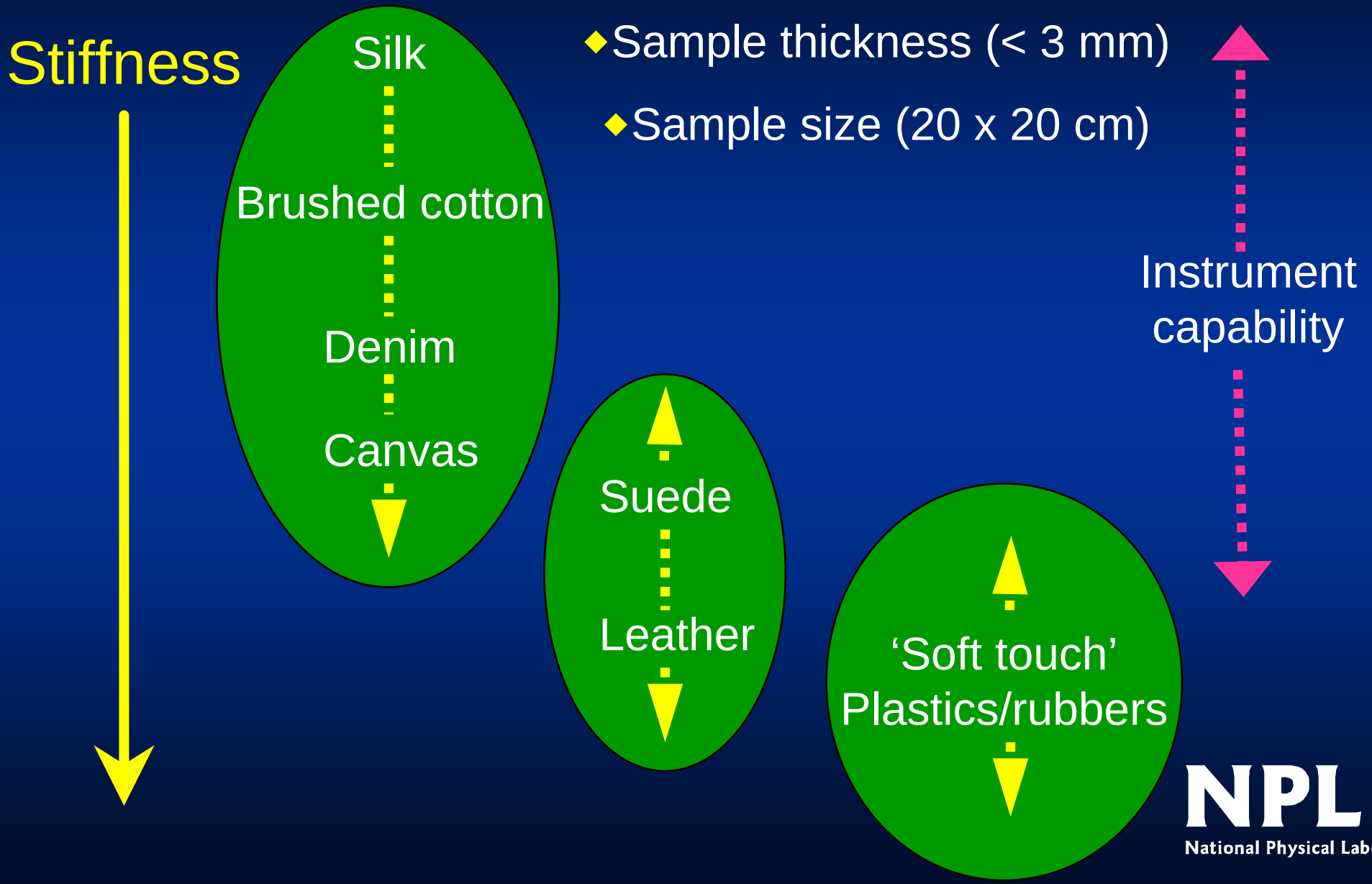
The ‘working range’ of KES instrumentation



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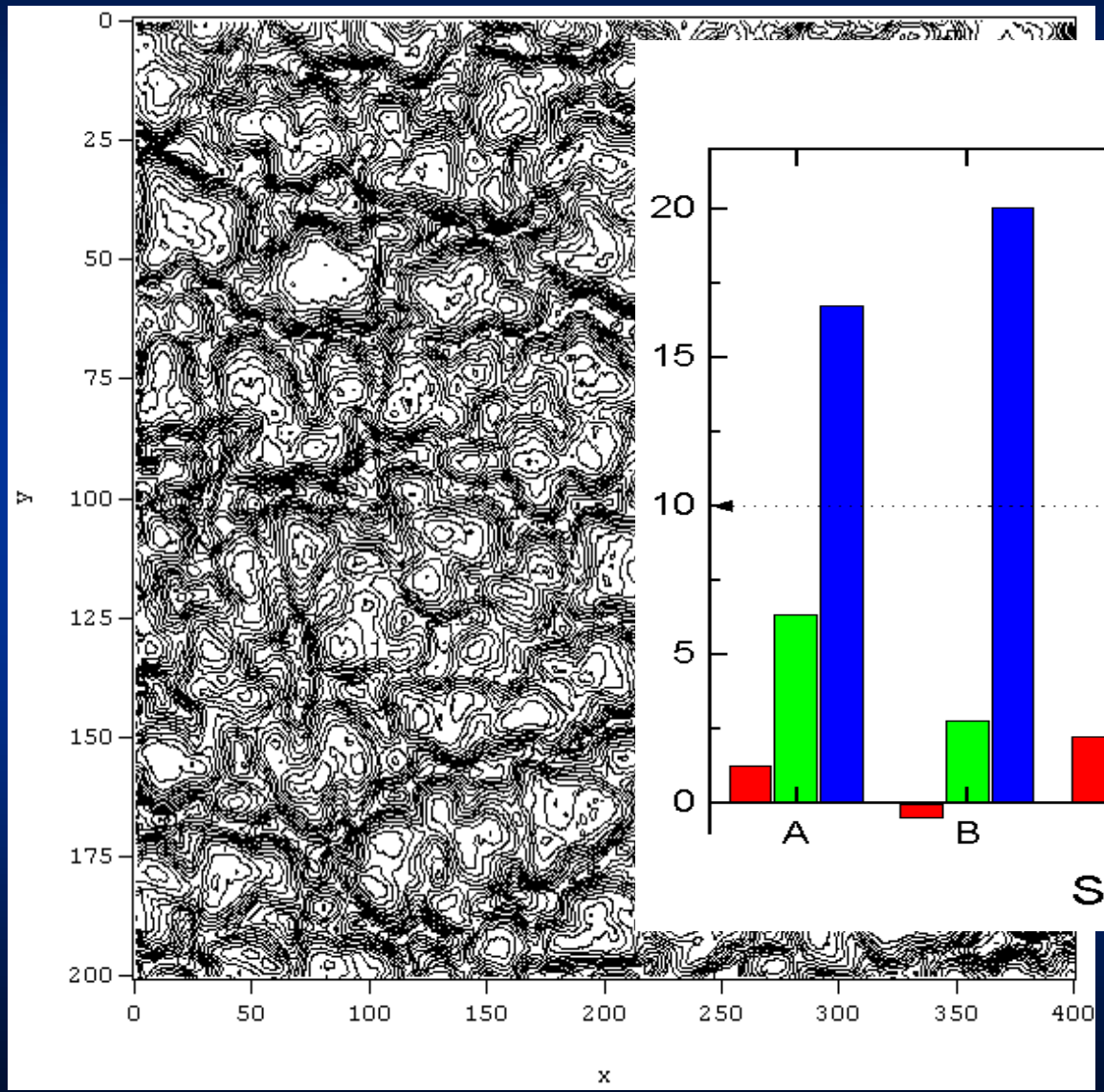
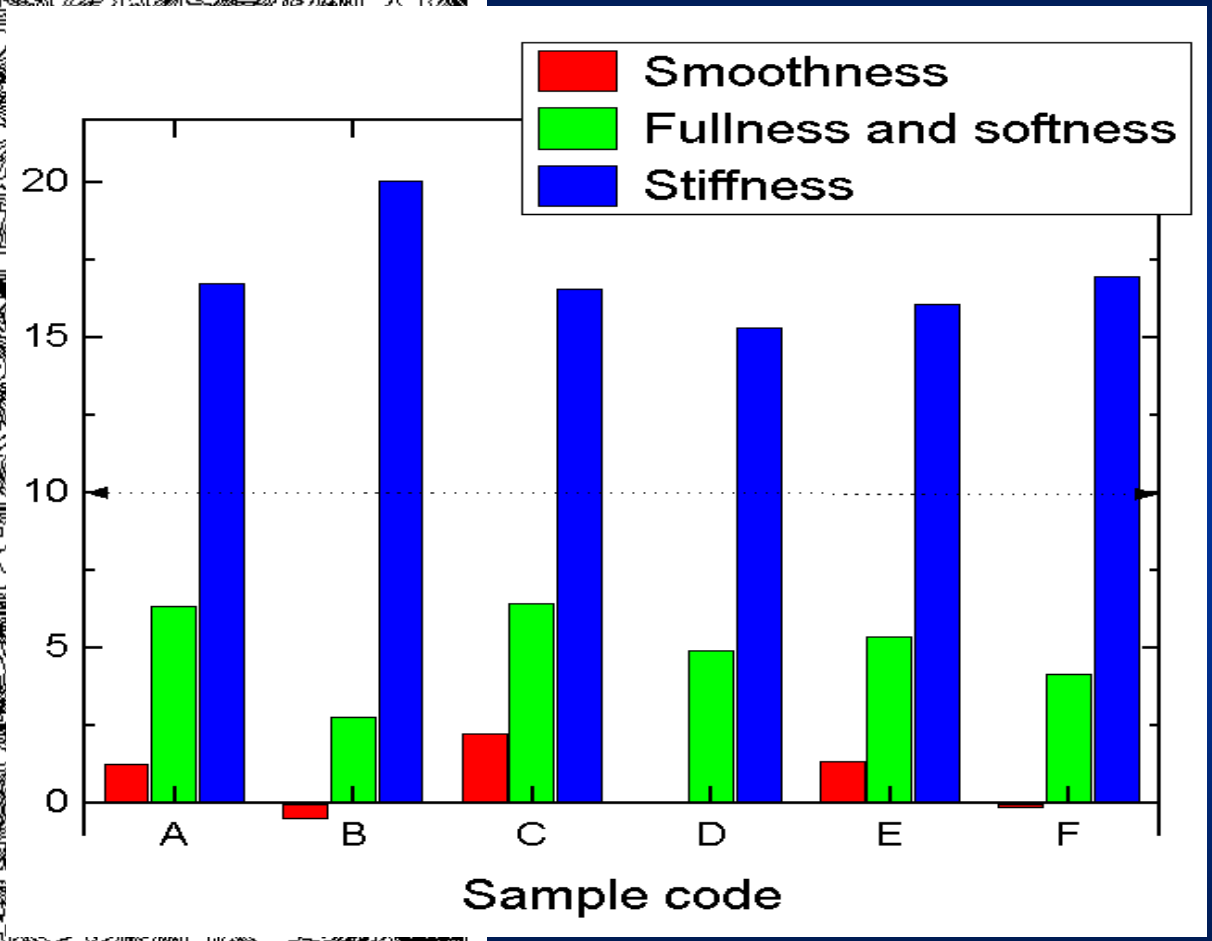
Proposed studio project: soft metrology of leather





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Polymeric materials:

Physical and sensory characterisation

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Sensory softness is a measure of:

Surface softness

- Smoothness, friction

Bulk softness

- A measure of compressibility – complex stresses

Warmth

Therefore physical measurements should aim to measure these properties

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Physical characterisation

- Surface friction
- Surface roughness

- Compressive performance
- Tensile performance
- Shear performance (obtained from tensile test and Poisson's ratio)
- Flexure

- Thermal diffusivity (thermal conductivity and specific heat capacity)

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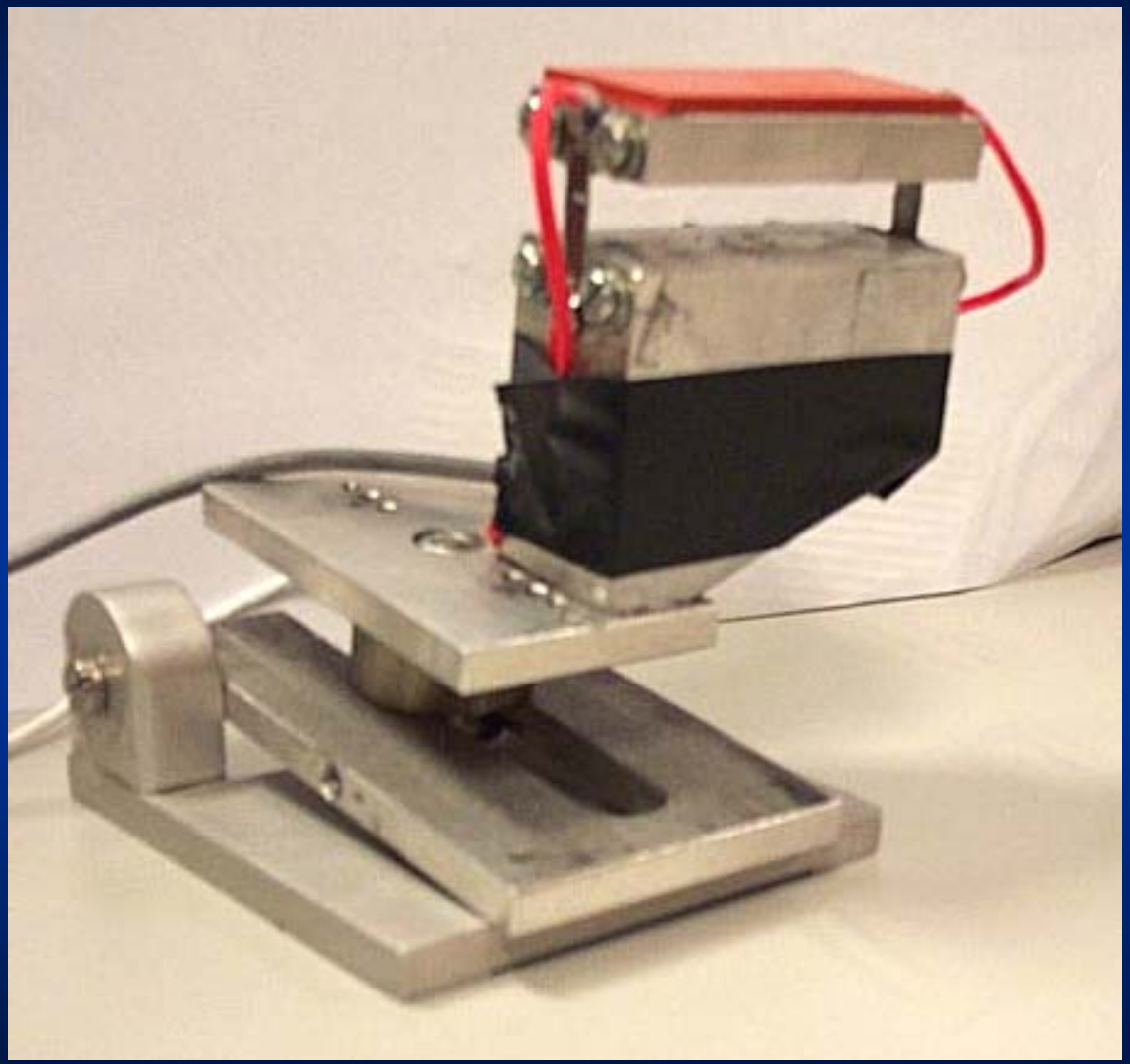
Surface friction measurements of soft materials



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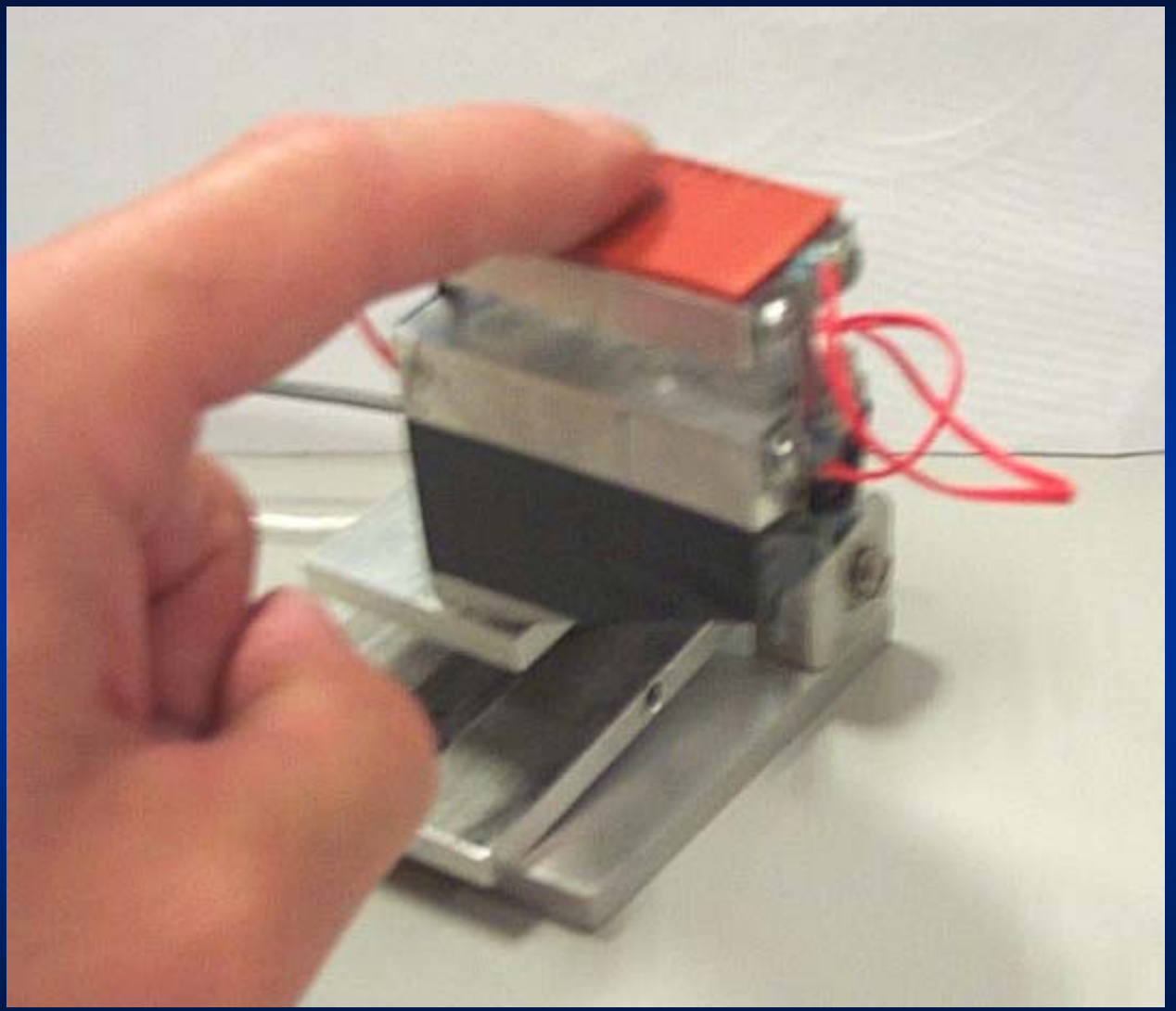
Surface friction measurements of soft materials



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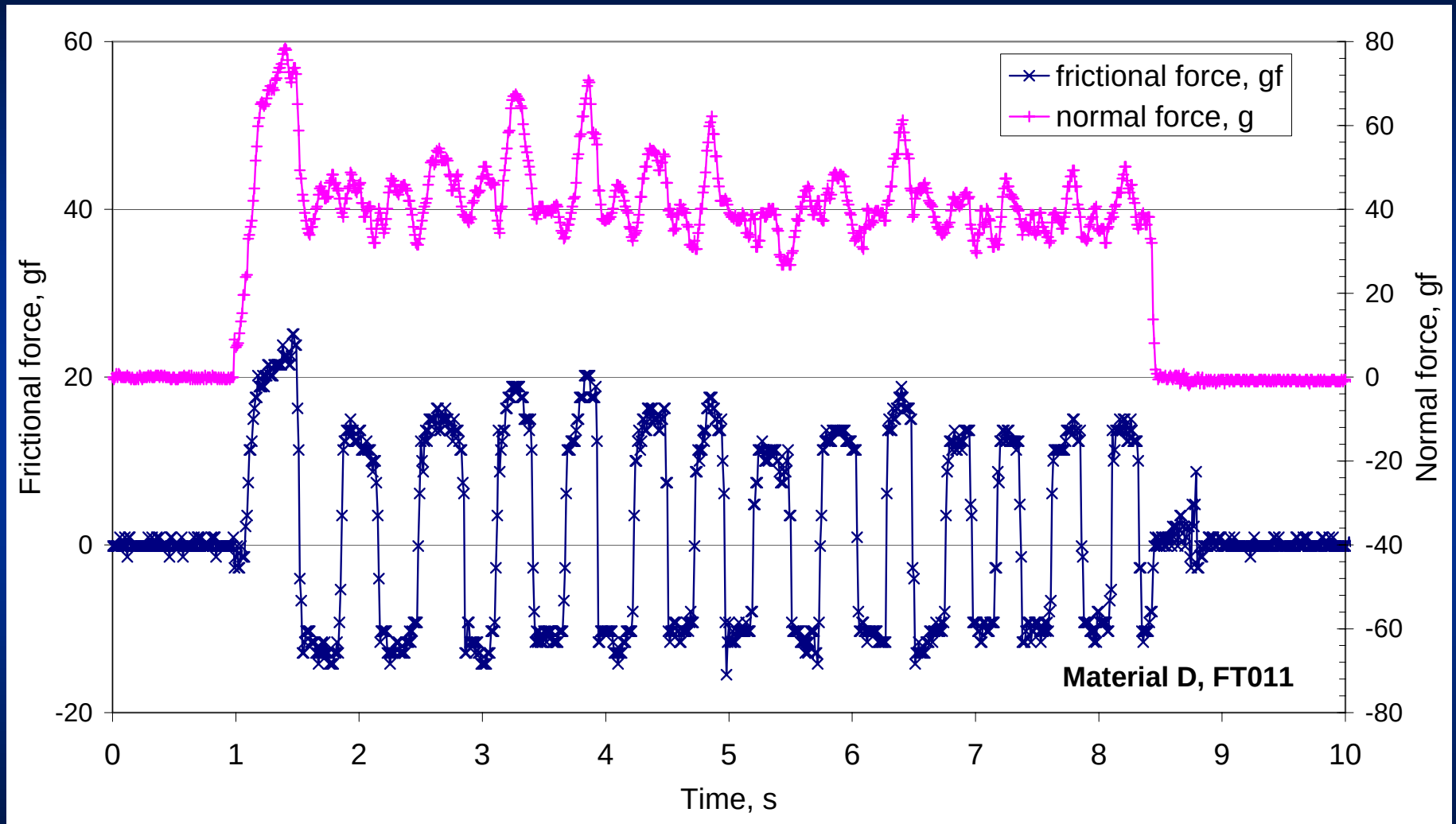
Surface friction measurements of soft materials



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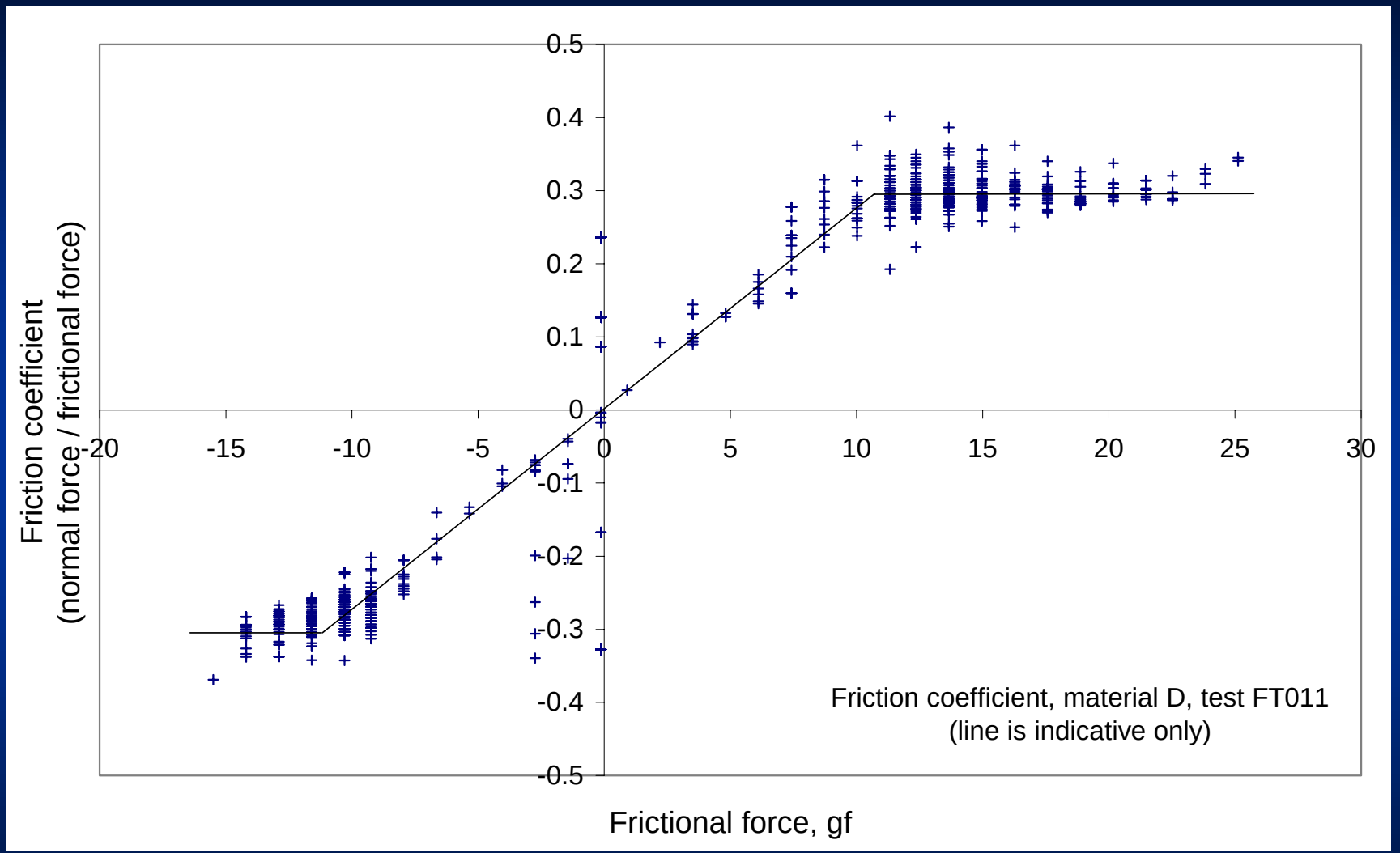
Surface friction measurements of soft materials



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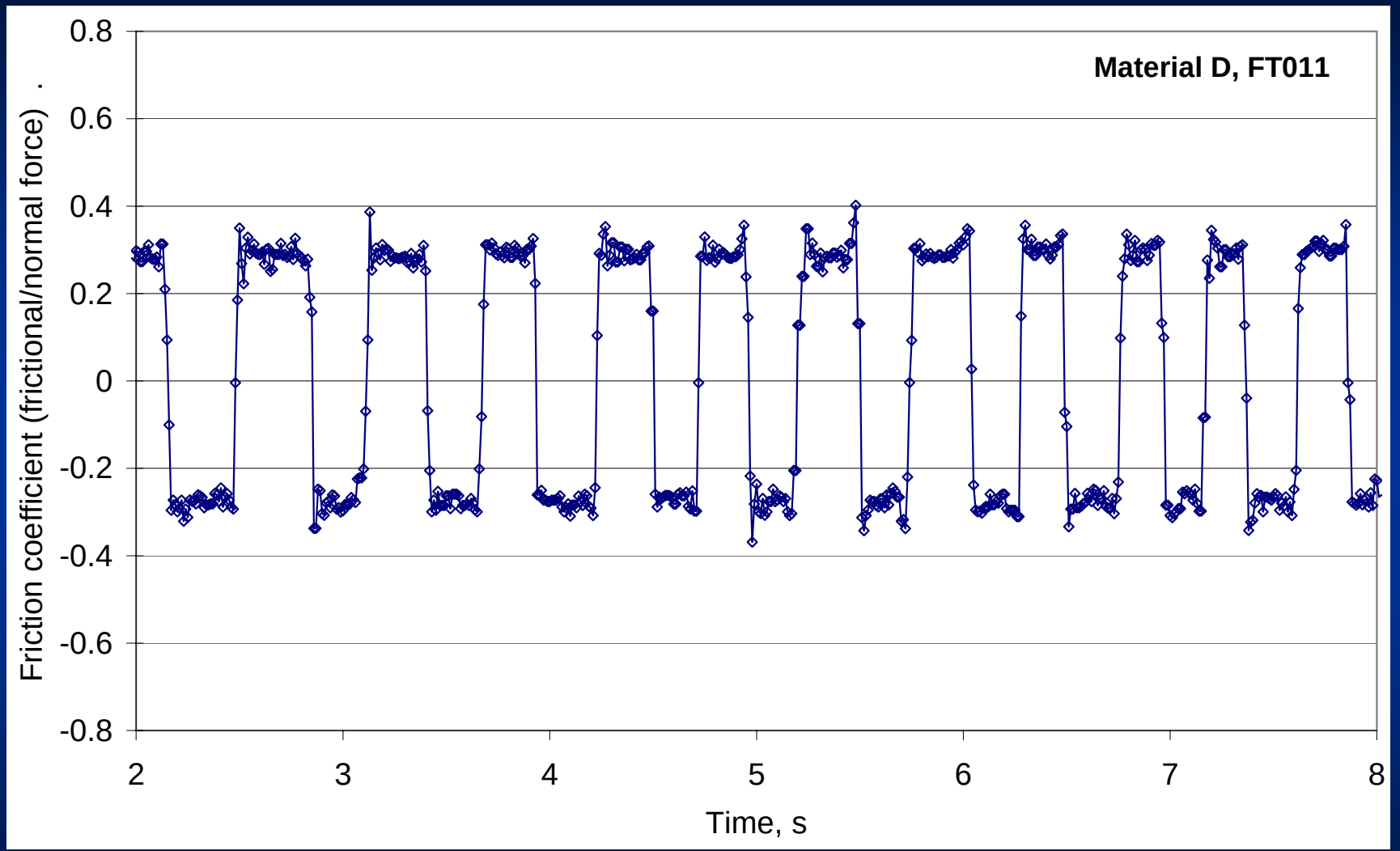
Surface friction measurements of soft materials



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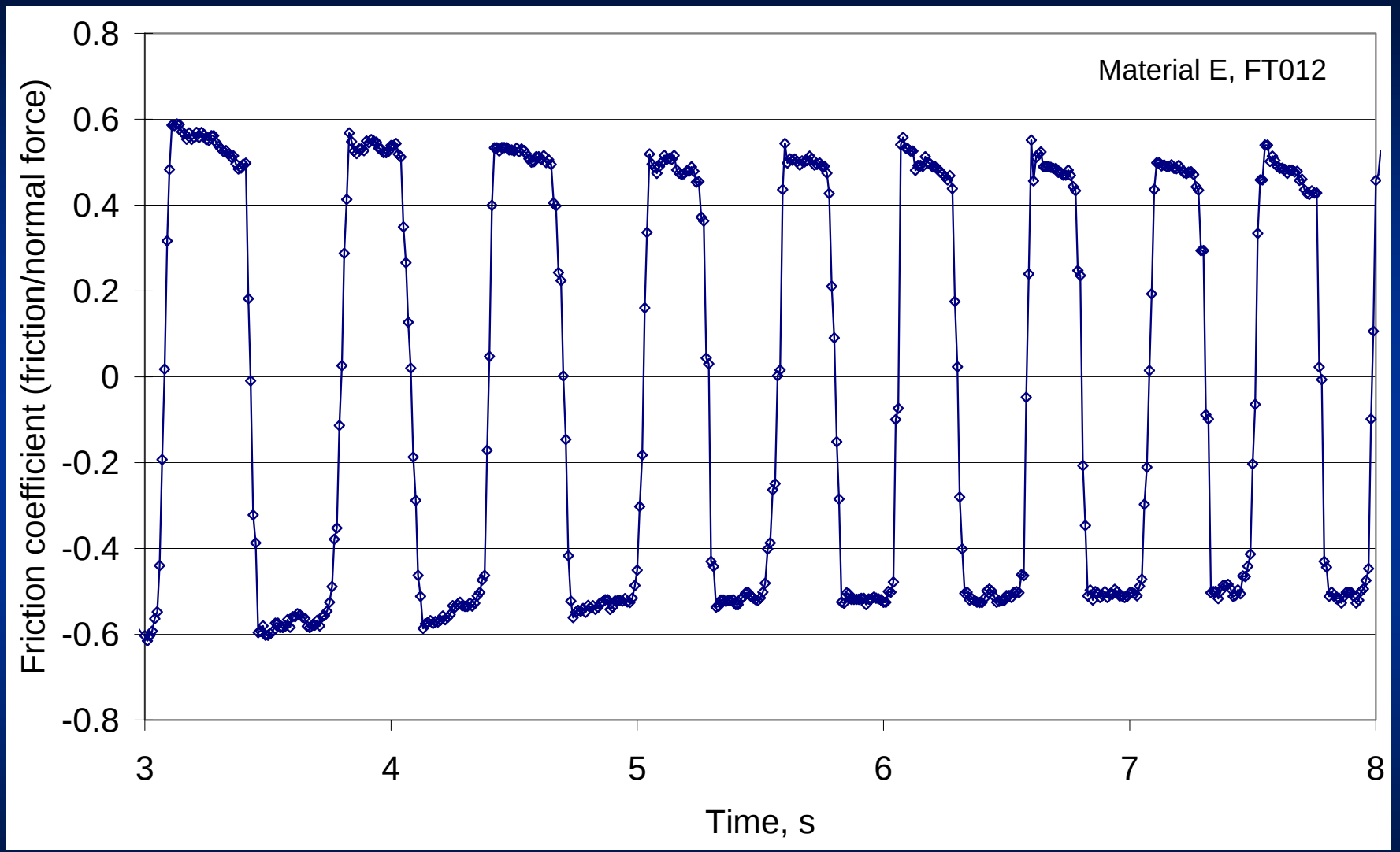
Surface friction measurements of soft materials



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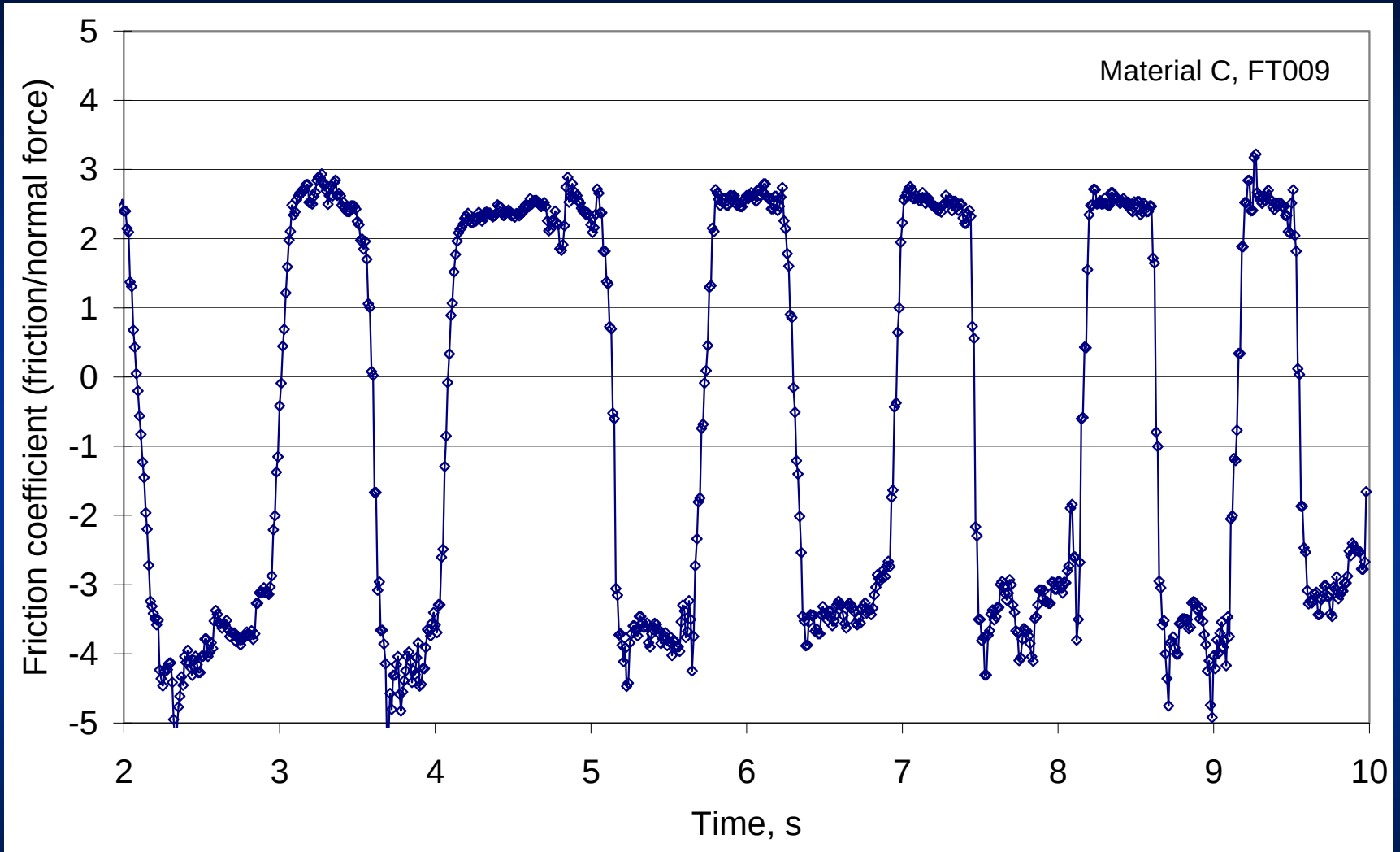
Surface friction measurements of soft materials



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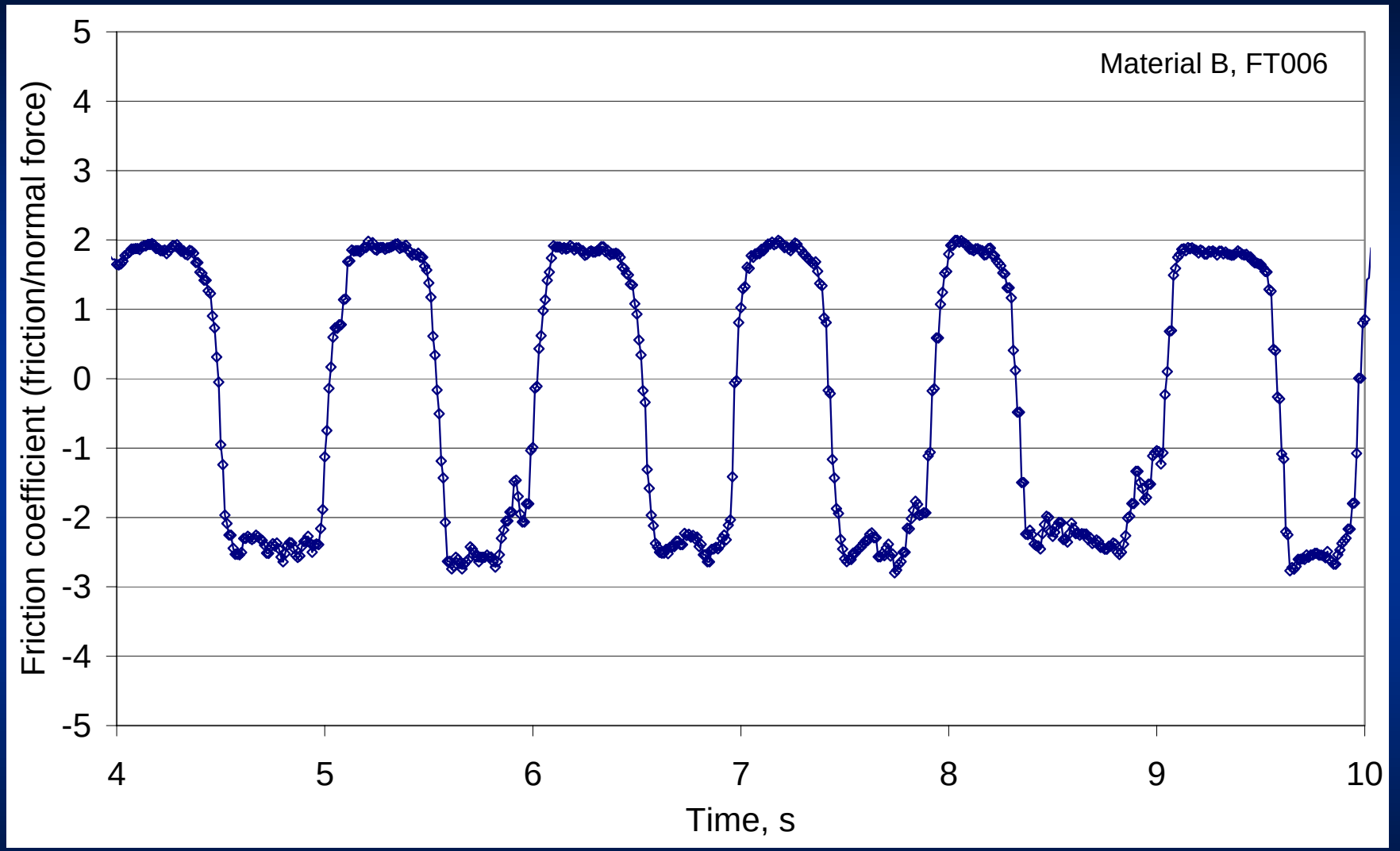
Surface friction measurements of soft materials



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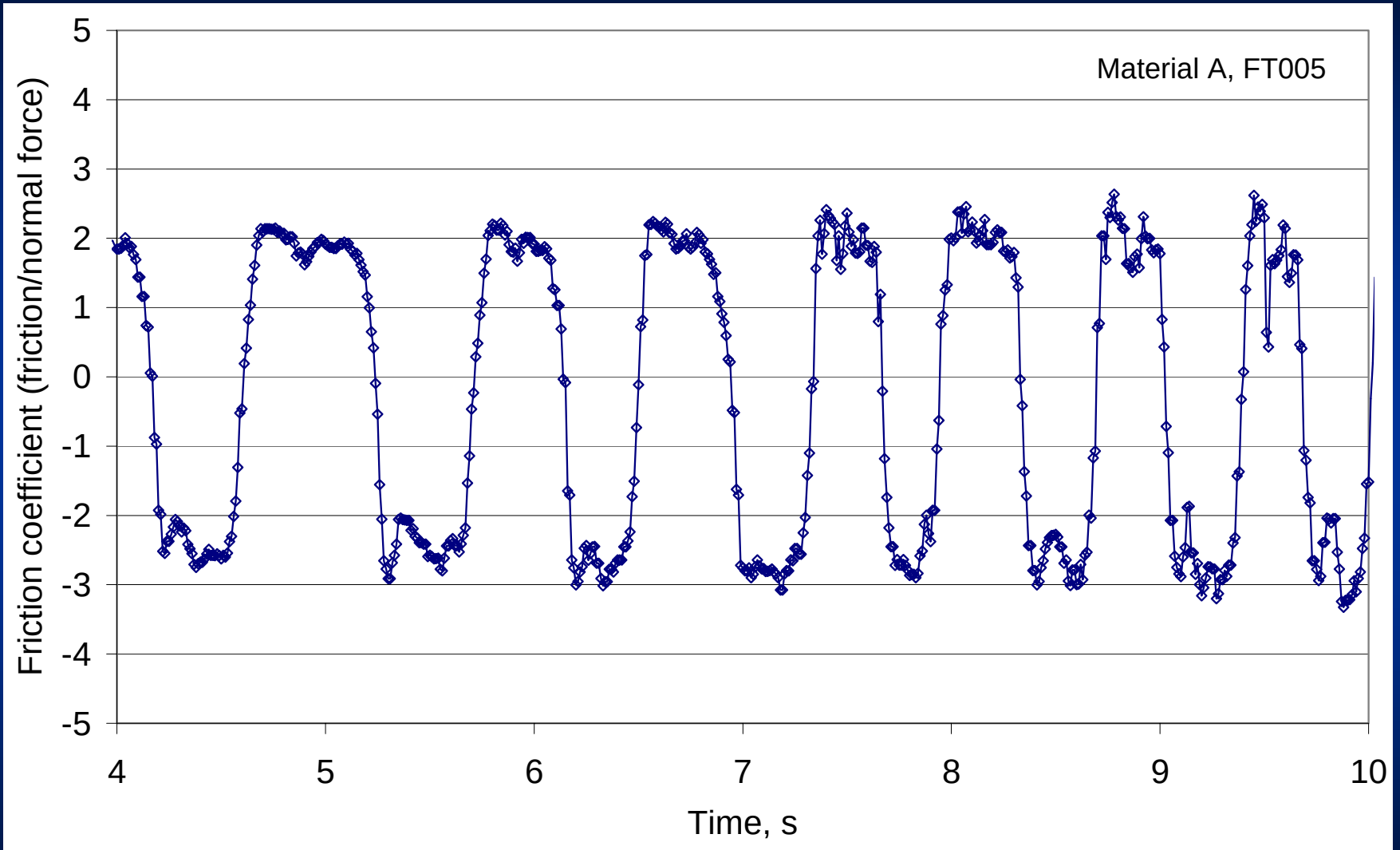
Surface friction measurements of soft materials



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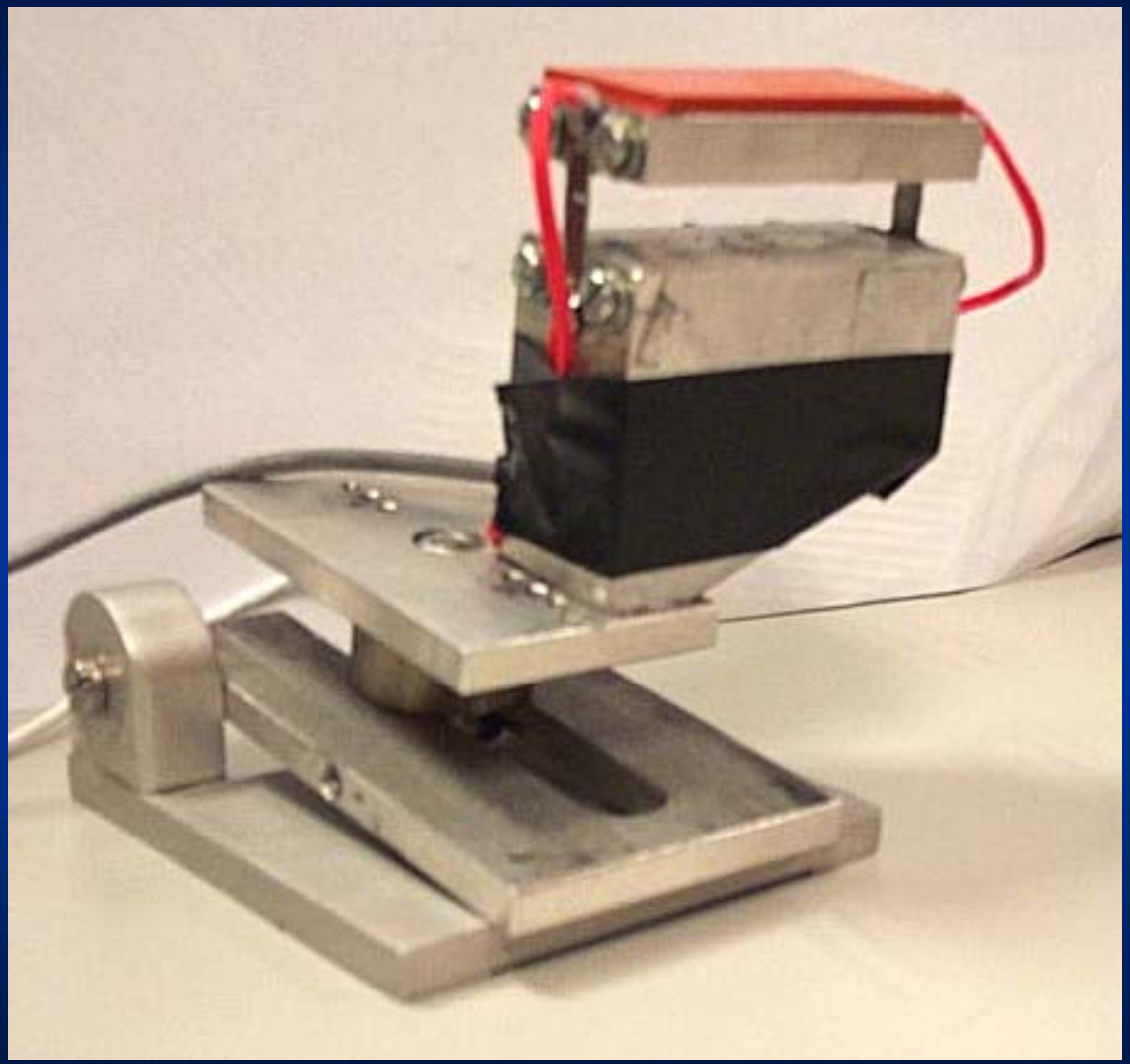
Surface friction measurements of soft materials



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Hardness data

					Average	Coeff. Var, %
Material E						
IRHD deadload	54.7	54.3		54	54.4	0.6
	54.5	54.7		54		
IRHD Micro	51.2	51.2		51.3	51.0	0.6
	50.9	50.7		50.9		
Material D						
IRHD deadload	66.6	65.6		66.4	66.8	1.1
	67.3	67.6		67.2		
IRHD Micro	64	64.1	62.1	61.6	63.1	1.6
				62.4		
	63.9	64		62.7		

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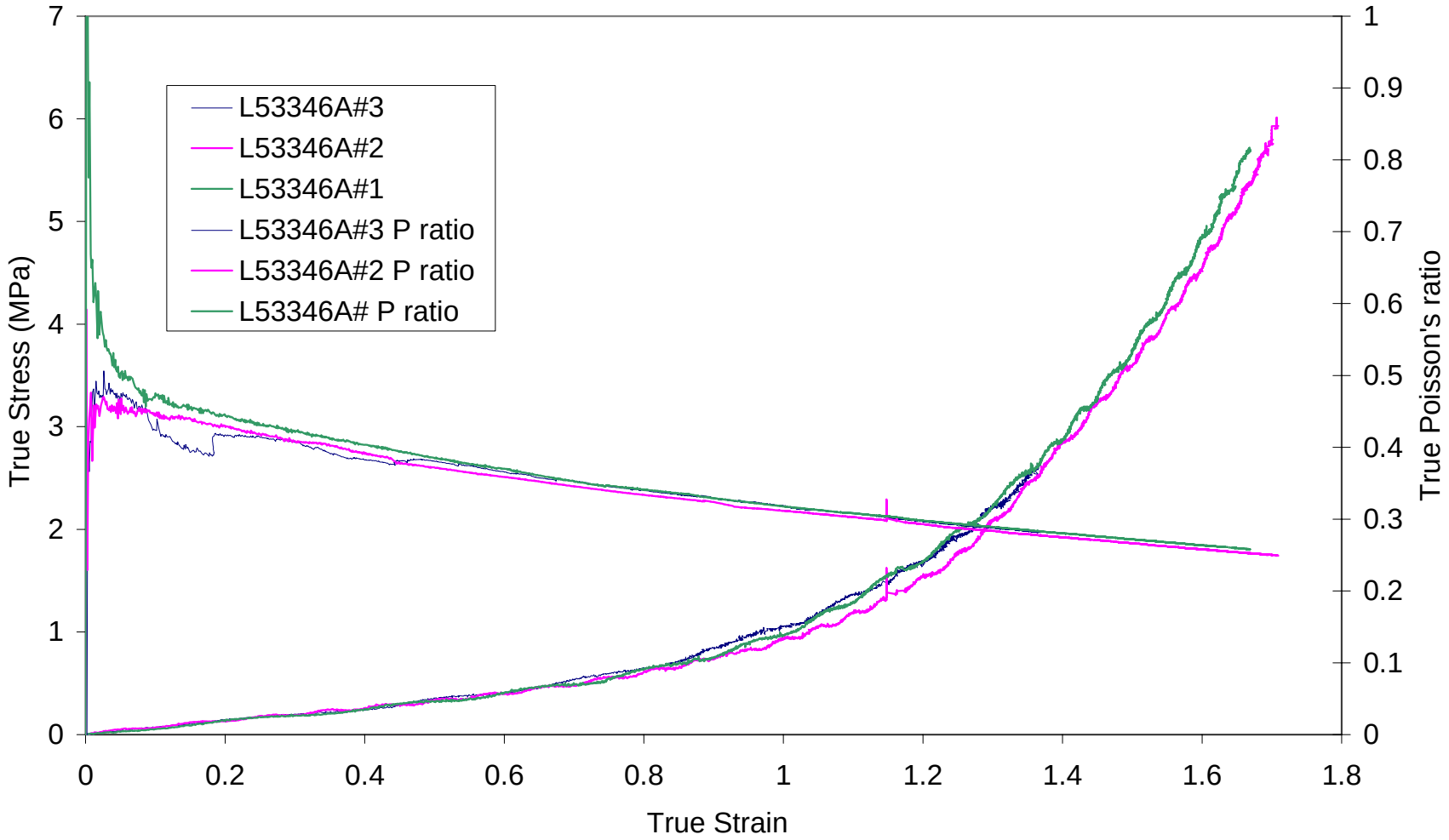
Tensile test data



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Sensory Panel Evaluation

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‘In house’ sensory panel evaluation

Soft touch materials ranked
and also graded on a scale of 1 to 10 for:

- Warmth
- Roughness
- Compressibility (hardness)
- Flexibility
- Moistness
- Tackiness/stickiness
- Friction
- Feeling ‘nice’
- Most suitable for use in a face mask
- Most suitable for use in a screwdriver handle

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Sensory test conditions

- 5 samples – washed and dried
- Assessments carried out in near darkness
- Thermally equilibrated samples
- Subjects washed and dried hands prior to assessment

Issues

- No time limit for assessment – issue for thermal assessment?
- Sample geometry

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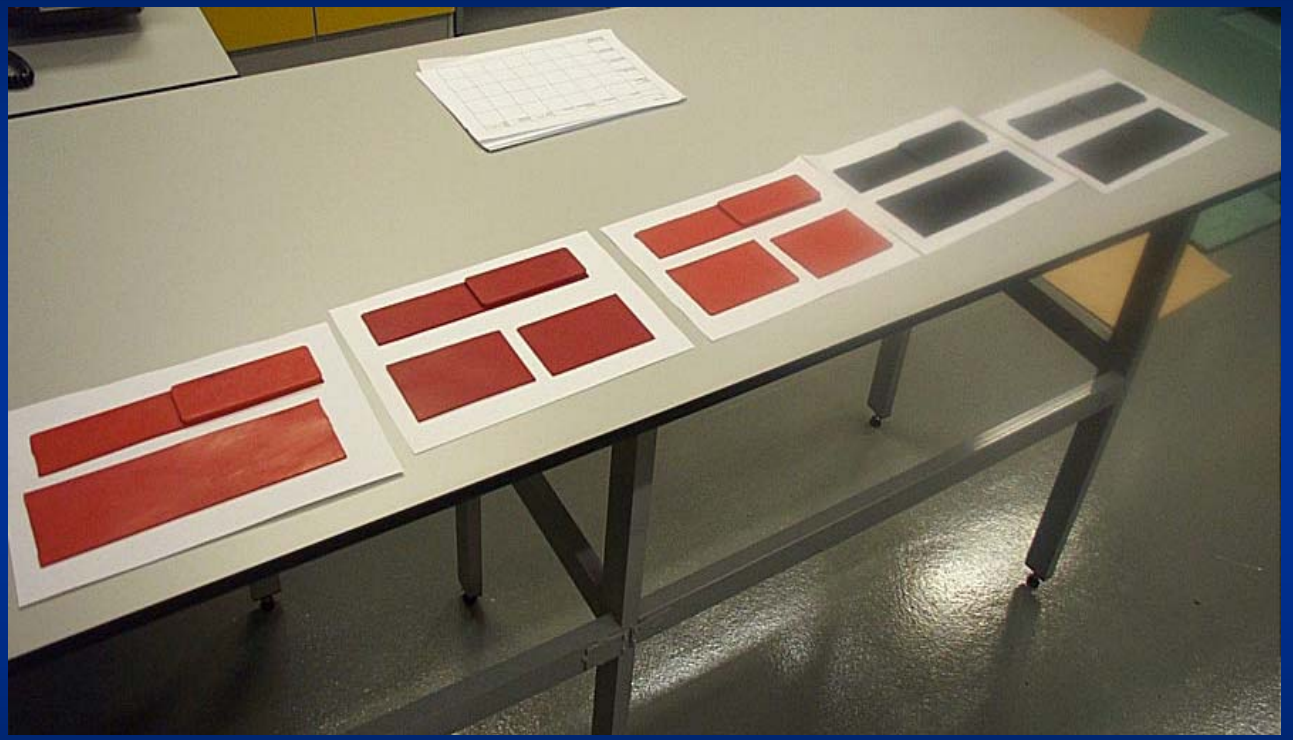
NPL sensory evaluation: samples and sampling



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Sensory panel results: average and indication of spread (range)

	Ranking (1-5)										Score (1-10)									
Material	warmth	roughness	hardness	flexibility	moistness	stickiness	friction	feel (nice = 1)	face mask suitability	screw driver suitability	warmth	roughness	hardness	flexibility	moistness	stickiness	friction	feel (nice = 1)	face mask suitability	screw driver suitability
C	1.3	1.6	4.0	1.7	1.8	1.2	1.0	4.0	3.3	3.0	9.2	8.2	2.5	9.0	7.8	9.8	10.0	2.8	5.0	5.2
B	2.0	3.2	3.3	2.5	2.8	2.5	2.3	2.5	1.5	2.3	9.0	6.6	3.0	8.0	5.8	6.7	8.0	6.2	9.5	7.5
E	4.2	4.8	2.0	4.0	3.7	4.2	5.0	2.0	3.5	2.8	1.7	1.0	8.5	2.5	3.0	1.8	1.0	7.7	4.0	5.7
D	4.7	3.0	1.0	4.8	4.2	4.7	4.0	2.5	3.5	3.0	1.2	5.4	10.0	1.0	2.3	1.2	2.3	6.3	3.5	5.3
A	2.7	2.2	4.7	1.5	2.0	1.8	2.7	3.8	3.2	3.7	7.7	7.0	1.2	9.5	7.3	8.7	8.0	3.5	5.0	3.7
range: (max-min)/2																				
C	0.5	0.5	1.0	1.0	1.5	0.5	0.0	2.0	2.0	2.0	1.5	2.5	2.0	2.0	4.5	0.5	0.0	4.5	4.5	4.5
B	1.0	1.0	1.0	0.5	1.5	1.0	0.5	1.5	1.0	1.0	1.0	3.5	1.5	1.5	4.5	3.5	1.0	4.0	1.0	2.5
E	0.5	0.5	0.0	0.0	2.0	0.5	0.0	1.5	1.5	2.0	0.5	0.0	0.5	1.0	4.5	1.0	0.0	4.0	3.0	4.5
D	0.5	2.0	0.0	0.5	1.5	0.5	0.0	2.0	1.5	2.0	0.5	4.5	0.0	0.0	3.5	0.5	0.5	4.5	3.5	4.5
A	0.5	1.0	0.5	1.0	1.0	1.0	0.5	1.0	2.0	1.0	1.5	2.5	0.5	1.0	3.5	1.5	1.0	3.5	4.5	3.0

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Sensory panel results: average and indication of spread (range)

	Average score (1-10)									
Material	warmth	roughness	hardness	flexibility	moistness	stickiness	friction	feel (nice = 1)	face mask suitability	screw driver suitability
C	9.2	8.2	2.5	9.0	7.8	9.8	10.0	2.8	5.0	5.2
B	9.0	6.6	3.0	8.0	5.8	6.7	8.0	6.2	9.5	7.5
E	1.7	1.0	8.5	2.5	3.0	1.8	1.0	7.7	4.0	5.7
D	1.2	5.4	10.0	1.0	2.3	1.2	2.3	6.3	3.5	5.3
A	7.7	7.0	1.2	9.5	7.3	8.7	8.0	3.5	5.0	3.7
range of score: (max-min)/2										
C	1.5	2.5	2.0	2.0	4.5	0.5	0.0	4.5	4.5	4.5
B	1.0	3.5	1.5	1.5	4.5	3.5	1.0	4.0	1.0	2.5
E	0.5	0.0	0.5	1.0	4.5	1.0	0.0	4.0	3.0	4.5
D	0.5	4.5	0.0	0.0	3.5	0.5	0.5	4.5	3.5	4.5
A	1.5	2.5	0.5	1.0	3.5	1.5	1.0	3.5	4.5	3.0

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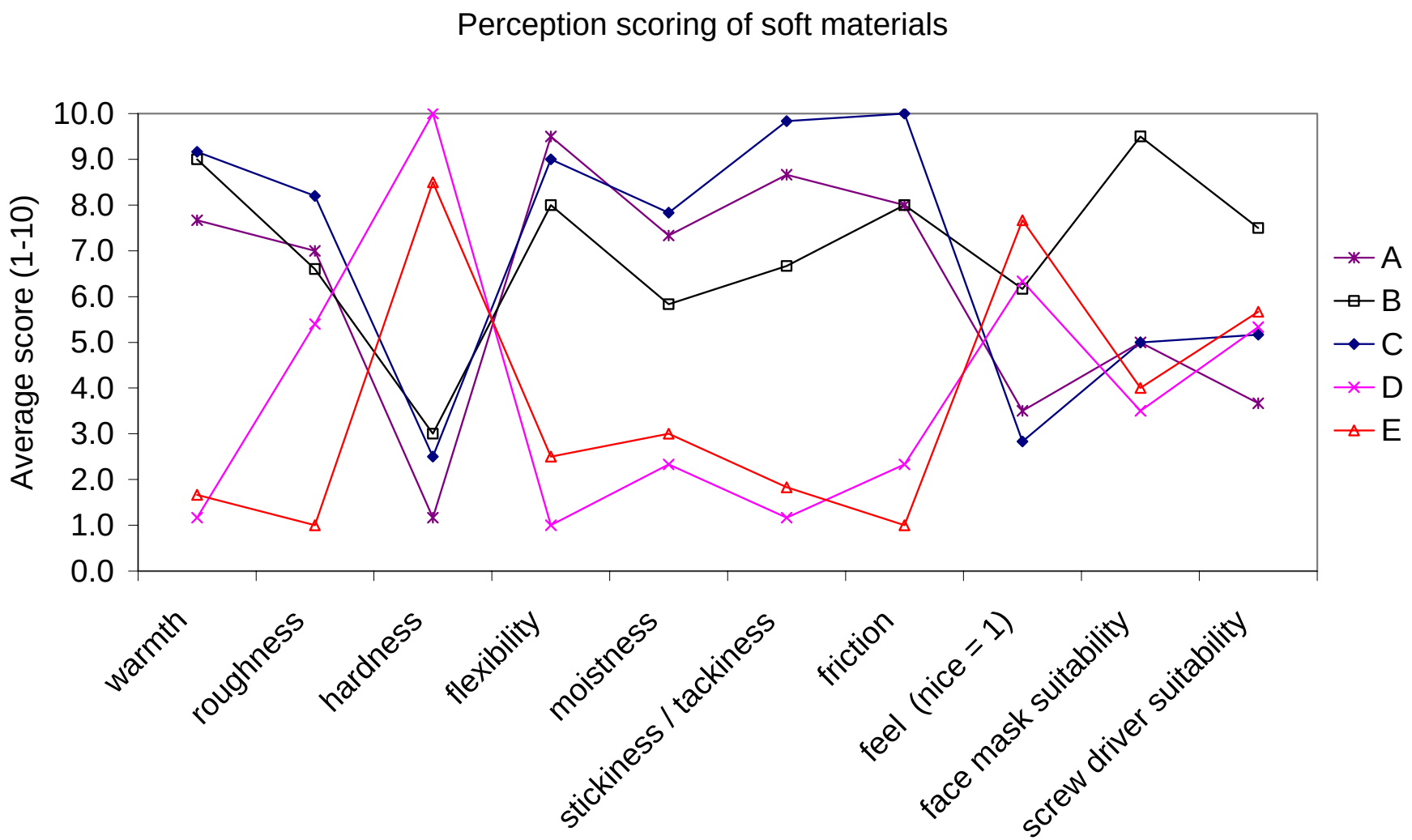
Multivariable assessment: Sensorogram



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Correlations of sensory panel results

	Correlation	Ranking (1-5)										Scoring (1-10)									
		warmth	*roughness*	*hardness*	*flexibility*	*moistness*	*stickiness*	*friction*	*feel (nice=1)*	*face mask suitability*	*screw driver suitability*	*warmth*	*roughness*	*hardness*	*flexibility*	*moistness*	*stickiness*	*friction*	*feel (nice=1)*	*face mask suitability*	*screw driver suitability*
Ranking (1-5)	warmth	1.00																			
	roughness	0.65	1.00																		
	hardness	-0.84	-0.62	1.00																	
	flexibility	0.89	0.67	-0.99	1.00																
	moistness	0.89	0.73	-0.97	0.99	1.00															
	stickiness	0.95	0.75	-0.94	0.98	0.99	1.00														
	friction	0.93	0.87	-0.74	0.81	0.84	0.90	1.00													
	feel (nice=1)	-0.68	-0.92	0.79	-0.82	-0.88	-0.85	-0.81	1.00												
	face mask suitability	0.48	0.00	-0.27	0.30	0.18	0.27	0.34	0.16	1.00											
	screw driver suitability	0.09	-0.42	0.37	-0.30	-0.35	-0.23	-0.04	0.62	0.63	1.00										
Scoring (1-10)	warmth	-0.97	-0.67	0.88	-0.92	-0.89	-0.94	-0.91	0.69	-0.57	-0.03	1.00									
	roughness	-0.73	-0.95	0.62	-0.68	-0.70	-0.75	-0.92	0.80	-0.30	0.20	0.78	1.00								
	hardness	0.89	0.65	-0.98	0.99	0.95	0.95	0.80	-0.76	0.43	-0.24	-0.95	-0.71	1.00							
	flexibility	-0.92	-0.67	0.98	-0.99	-0.96	-0.97	-0.84	0.77	-0.42	0.21	0.96	0.72	-1.00	1.00						
	moistness	-0.92	-0.76	0.96	-0.99	-0.99	-1.00	-0.89	0.87	-0.27	0.29	0.94	0.76	-0.97	0.98	1.00					
	stickiness	-0.94	-0.78	0.95	-0.98	-0.99	-1.00	-0.91	0.87	-0.28	0.26	0.95	0.79	-0.96	0.98	1.00	1.00				
	friction	-0.95	-0.83	0.86	-0.91	-0.91	-0.96	-0.97	0.81	-0.42	0.11	0.97	0.89	-0.92	0.94	0.95	0.97	1.00			
	feel (nice=1)	0.72	0.94	-0.79	0.82	0.88	0.87	0.85	-1.00	-0.10	-0.56	-0.72	-0.84	0.77	-0.79	-0.88	-0.88	-0.85	1.00		
	face mask suitability	-0.60	-0.07	0.39	-0.42	-0.31	-0.39	-0.44	-0.05	-0.99	-0.61	0.67	0.35	-0.53	0.53	0.39	0.40	0.53	0.00	1.00	
	screw driver suitability	-0.12	0.40	-0.31	0.25	0.32	0.20	0.01	-0.60	-0.73	-0.99	0.09	-0.14	0.17	-0.15	-0.25	-0.22	-0.06	0.54	0.70	1.00

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Correlations of sensory panel results

		Ranking (1-5)									
	Confidence	H	M	H	H	L	H	H	L	L	L
	Correlation	*warmth*	*roughness*	*hardness*	*flexibility*	*moistness*	*stickiness*	*friction*	*feel (nice=1)*	*face mask suitability*	*screw driver suitability*
Scoring (1-10)	warmth	-0.97	-0.67	0.88	-0.92	-0.89	-0.94	-0.91	0.69	-0.57	-0.03
	roughness	-0.73	-0.95	0.62	-0.68	-0.70	-0.75	-0.92	0.80	-0.30	0.20
	hardness	0.89	0.65	-0.98	0.99	0.95	0.95	0.80	-0.76	0.43	-0.24
	flexibility	-0.92	-0.67	0.98	-0.99	-0.96	-0.97	-0.84	0.77	-0.42	0.21
	moistness	-0.92	-0.76	0.96	-0.99	-0.99	-1.00	-0.89	0.87	-0.27	0.29
	stickiness	-0.94	-0.78	0.95	-0.98	-0.99	-1.00	-0.91	0.87	-0.28	0.26
	friction	-0.95	-0.83	0.86	-0.91	-0.91	-0.96	-0.97	0.81	-0.42	0.11
	feel (nice=1)	0.72	0.94	-0.79	0.82	0.88	0.87	0.85	-1.00	-0.10	-0.56
	face mask suitability	-0.60	-0.07	0.39	-0.42	-0.31	-0.39	-0.44	-0.05	-0.99	-0.61
	screw driver suitability	-0.12	0.40	-0.31	0.25	0.32	0.20	0.01	-0.60	-0.73	-0.99

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Correlations of sensory panel results

		Scoring (1-10)									
	Confidence	H	M	H	H	L	H	H	L	L	L
	Correlation	*warmth*	*roughness*	*hardness*	*flexibility*	*moistness*	*stickiness*	*friction*	*feel (nice=1)*	*face mask suitability*	*screw driver suitability*
Scoring (1-10)	warmth	1.00									
	roughness	0.78	1.00								
	hardness	-0.95	-0.71	1.00							
	flexibility	0.96	0.72	-1.00	1.00						
	moistness	0.94	0.76	-0.97	0.98	1.00					
	stickiness	0.95	0.79	-0.96	0.98	1.00	1.00				
	friction	0.97	0.89	-0.92	0.94	0.95	0.97	1.00			
	feel (nice=1)	-0.72	-0.84	0.77	-0.79	-0.88	-0.88	-0.85	1.00		
	face mask suitability	0.67	0.35	-0.53	0.53	0.39	0.40	0.53	0.00	1.00	
	screw driver suitability	0.09	-0.14	0.17	-0.15	-0.25	-0.22	-0.06	0.54	0.70	1.00

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Summary

- Limitations of using Kawabata Evaluation System for soft touch polymeric materials identified. Alternative methods being identified / developed.
- Surface friction and other thermal/mechanical measurements commenced.
- Sensory panel development initiated.
- Initial sensory panel assessment carried out on selection of materials.
- Potential studio project on soft metrology of leathers

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Next steps

- Further identification and development of characterisation methods.
- Sensory panel development.
- Obtain further specimens.
- Progress potential studio project on soft metrology of leathers

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THE END

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‘Next Steps’ described at the last IAG

- Agree a protocol for the sensory panel
- Obtain specimens
- Pursue Kawabata test system modifications
- Evaluate other methods for measuring properties

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Comparisons between physical properties and sensory evaluation

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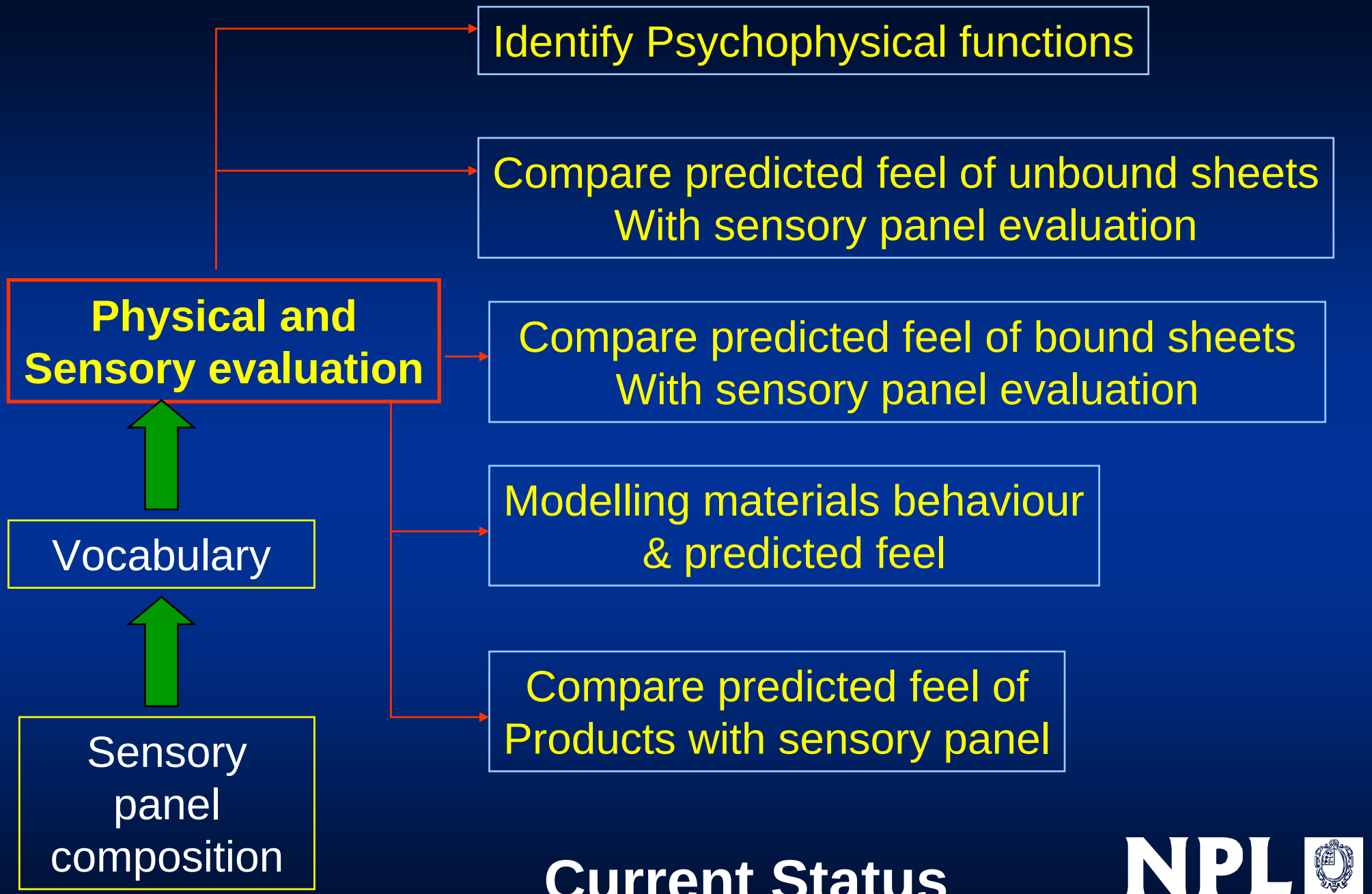

Current Status

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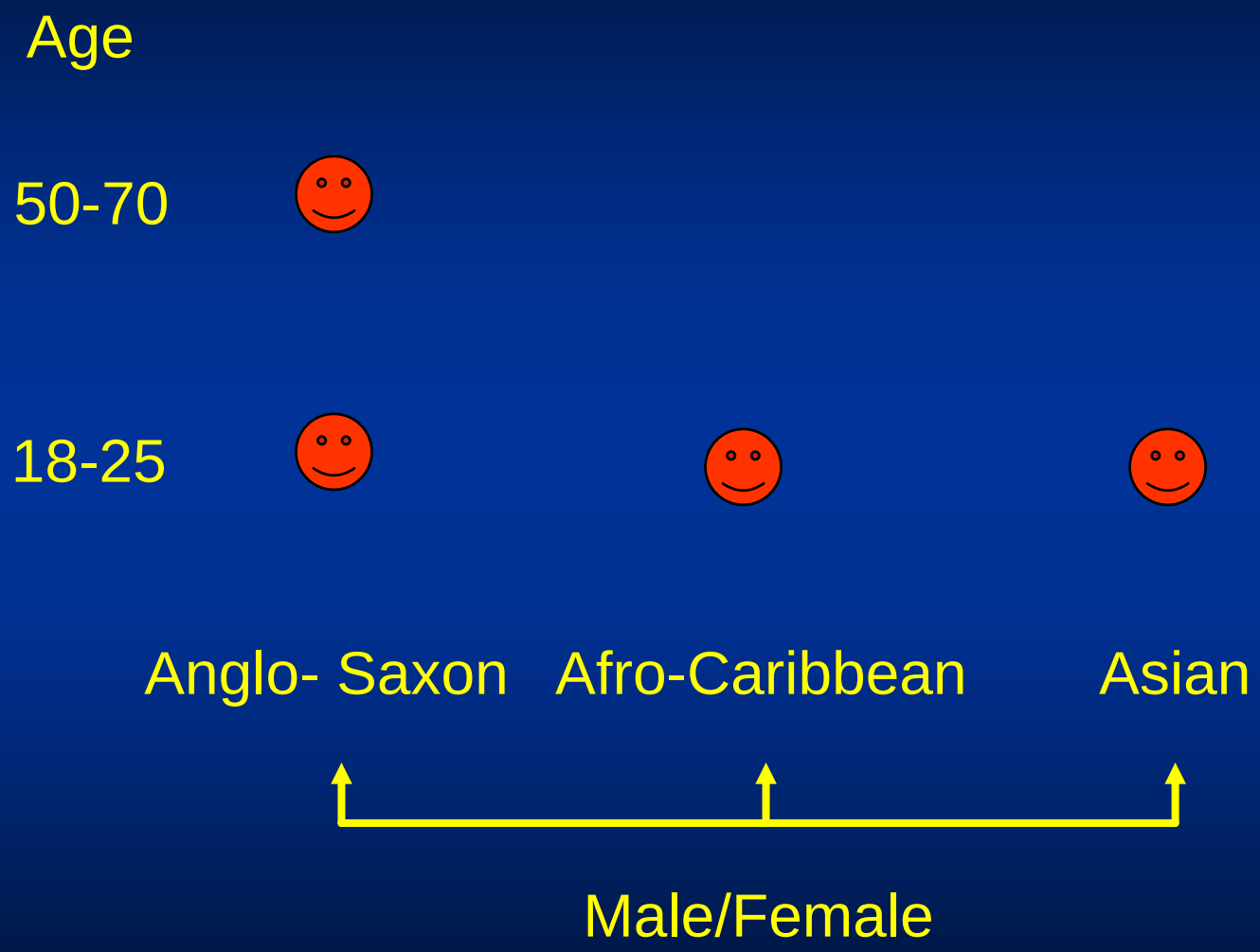
Panel composition



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Summary

- Matrix of materials established
- Sensory Panel development initiated
- Preliminary property testing highlights difficulty with Kawabata

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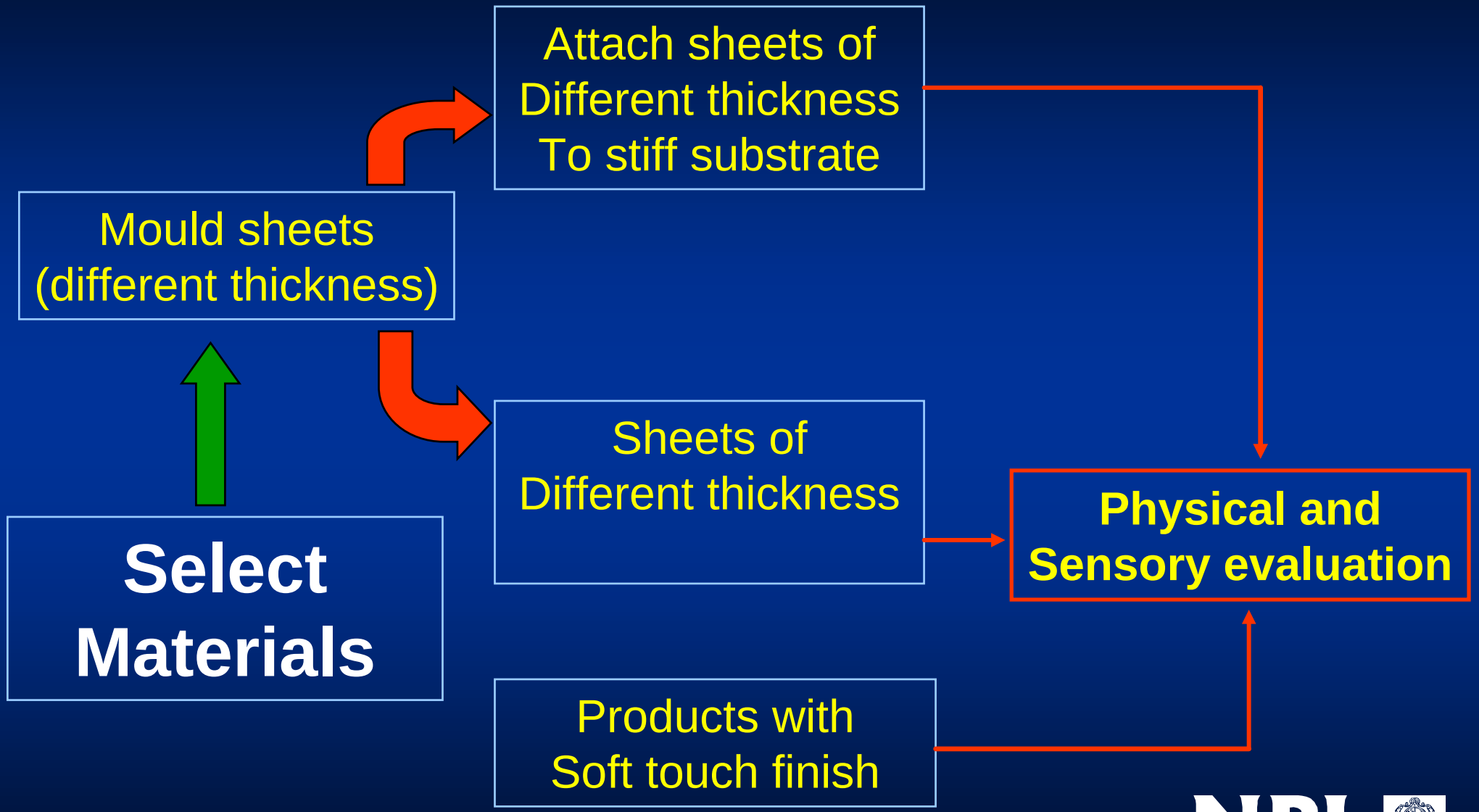
Prepare test specimens – Current Status



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Sensory panel evaluation – objective tests

- Triangle test – odd one out in a set of three
- Paired comparison test – compare pairs
- Duo-trio test – control followed by two samples, one of which is control, identify odd one out.
- Ranking test

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Sensory panel evaluation – subjective tests

- Intensity measurements – intensity of an attribute (e.g. scale of 1 to 10)
- Profile analyses – sensory description of material

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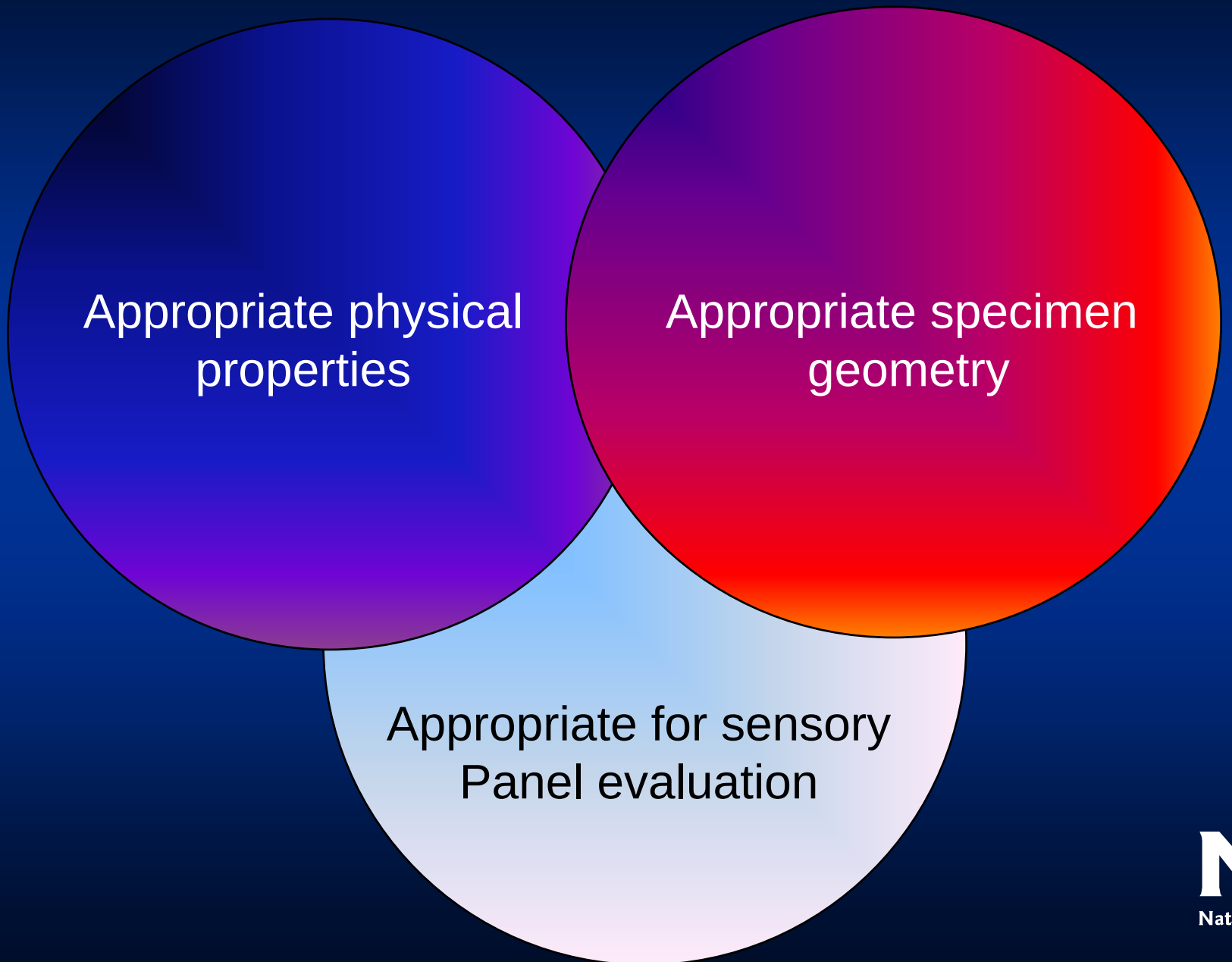
Materials selection criteria



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Measurable properties typically found in data sheets

- Hardness
- Density
- Coefficient of thermal expansion

- Processing data (melt flow rate)

- Tensile properties (strength, modulus, elongation to break)
- Flexural properties (modulus, fatigue)
- Torsion modulus
- Wear

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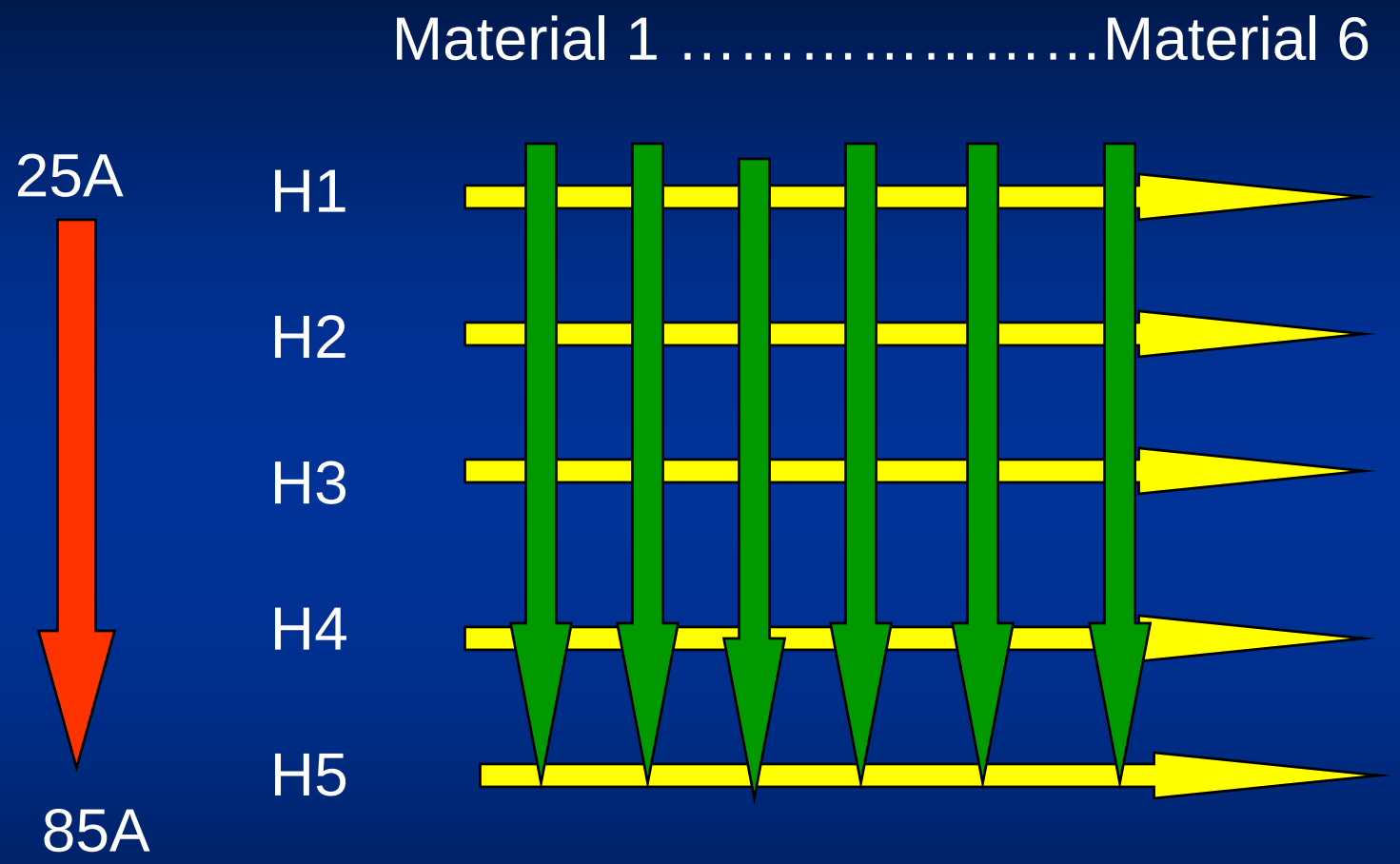
Choice of Materials



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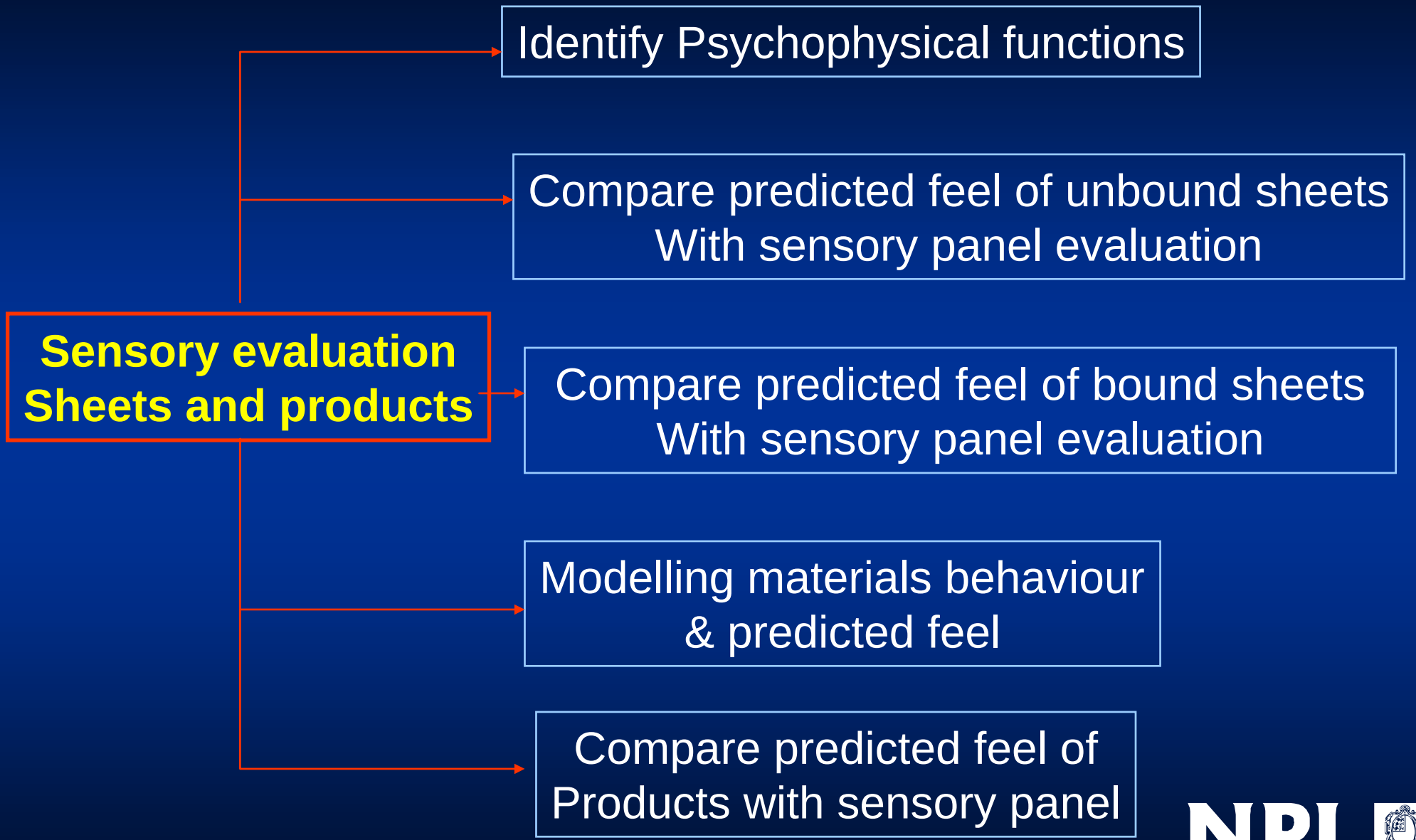

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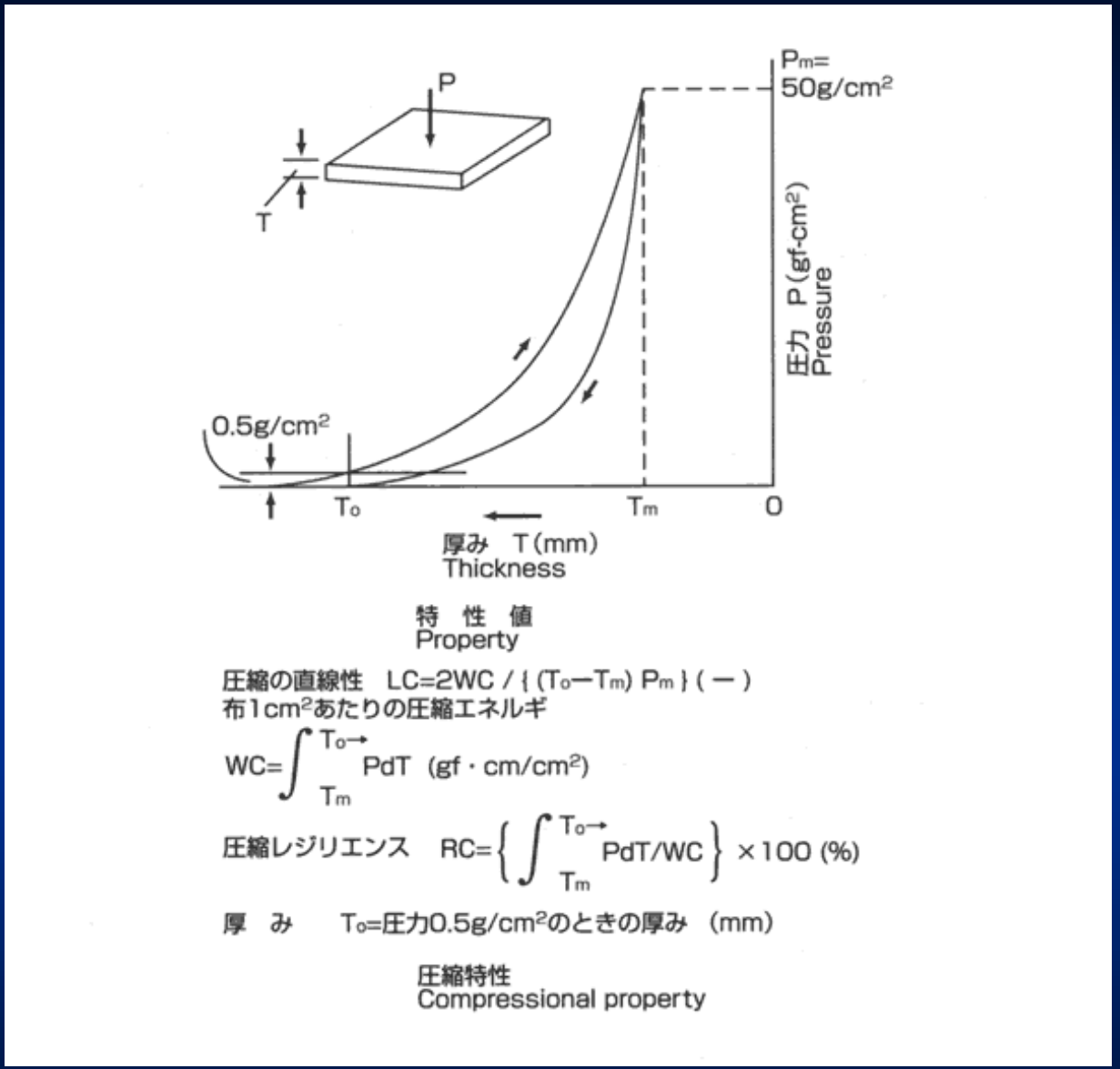
Compressibility



特 性 値
Property

圧縮の直線性 $LC=2WC / \{ (T_o - T_m) P_m \}$ (一)
布1cm²あたりの圧縮エネルギ

$$WC=\int_{T_m}^{T_o} PdT \quad (gf \cdot cm/cm^2)$$

圧縮レジリエンス $RC=\left\{ \int_{T_m}^{T_o} PdT/WC \right\} \times 100$ (%)

厚 み T_o=圧力0.5g/cm²のときの厚み (mm)

圧縮特性
Compressional property

Kesato, Japan

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Factors affecting perception

- Appearance
- Comfort
- Tackiness
- Warmth
- Dryness
- Compressibility

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Physical properties

Property	Data sheet
Surface roughness	
Coefficient of Friction	
Tensile modulus	yes
Shear modulus	
Flexural modulus	
Compressibility / hardness	yes
Density	yes
Heat transfer	

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Indenter geometry, force and hardness

Test method	Diameter of indenter, / mm	Contact force, / N	Additional force, / N	Total force, / N	Application
N	2,50 ± 0,01	0,30 ± 0,02	5,40 ± 0,01	5,70 ± 0,03	Thickness: = 4 mm, Range: 35 - 85 IRHD, or 30 - 95 IRHD
H	1,00 ± 0,01	0,30 ± 0,02	5,40 ± 0,01	5,70 ± 0,03	Thickness: = 4 mm, Range: 85 - 100 IRHD
L	5,00 ± 0,01	0,30 ± 0,02	5,40 ± 0,01	5,70 ± 0,03	Thickness: = 6 mm, Range: 10 - 35 IRHD
M	0,395 ± 0,005	0,008 3 ± 0,000 5	0,145 ± 0,000 5	0,153 3 ± 0,001	Thickness: < 4 mm, Range: 35 - 85 IRHD, or 30 - 95 IRHD

(NPL website)

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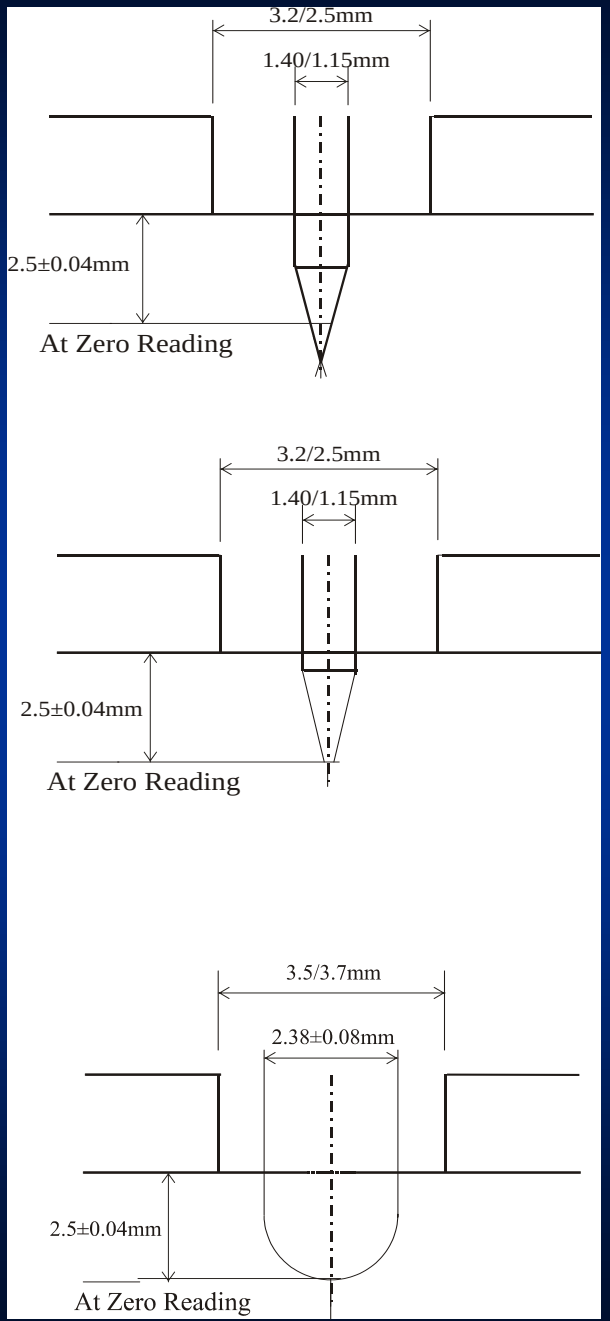
Indenter geometry

Type A&C

Type B&D

Types DO, O and OO



(ASTM D 2240-97)

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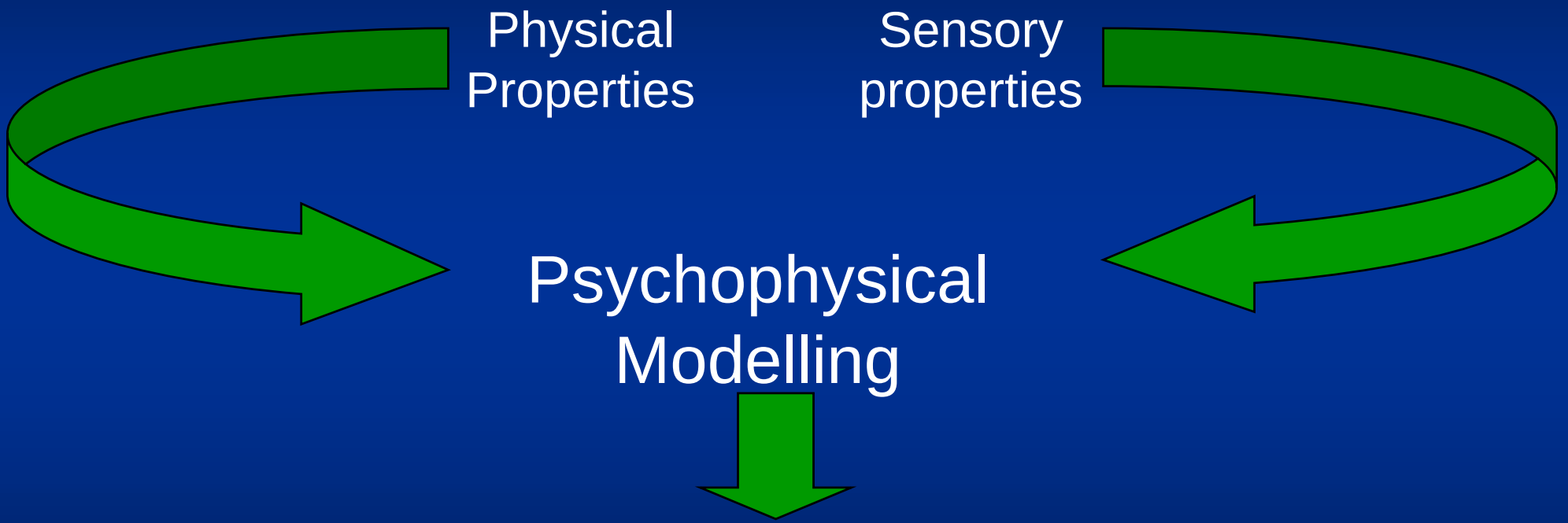
Linking physical measurement with sensory perception



S= x*stiffness+y*roughness+…….

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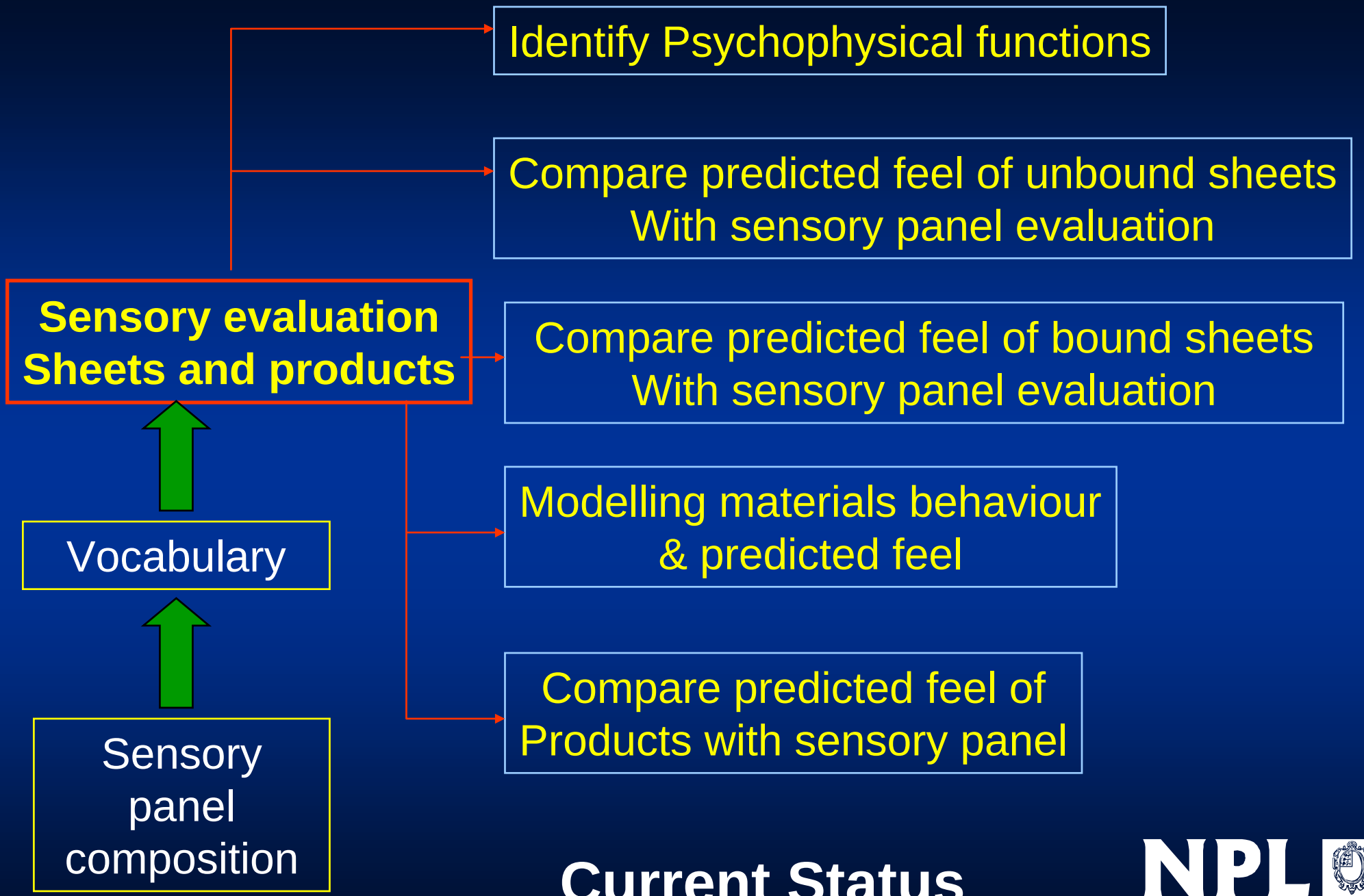

Current Status

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Samples ranging from x to y shore - Kawabata

Sample

Preliminary results:

- Too small
- Too stiff
- Too thick

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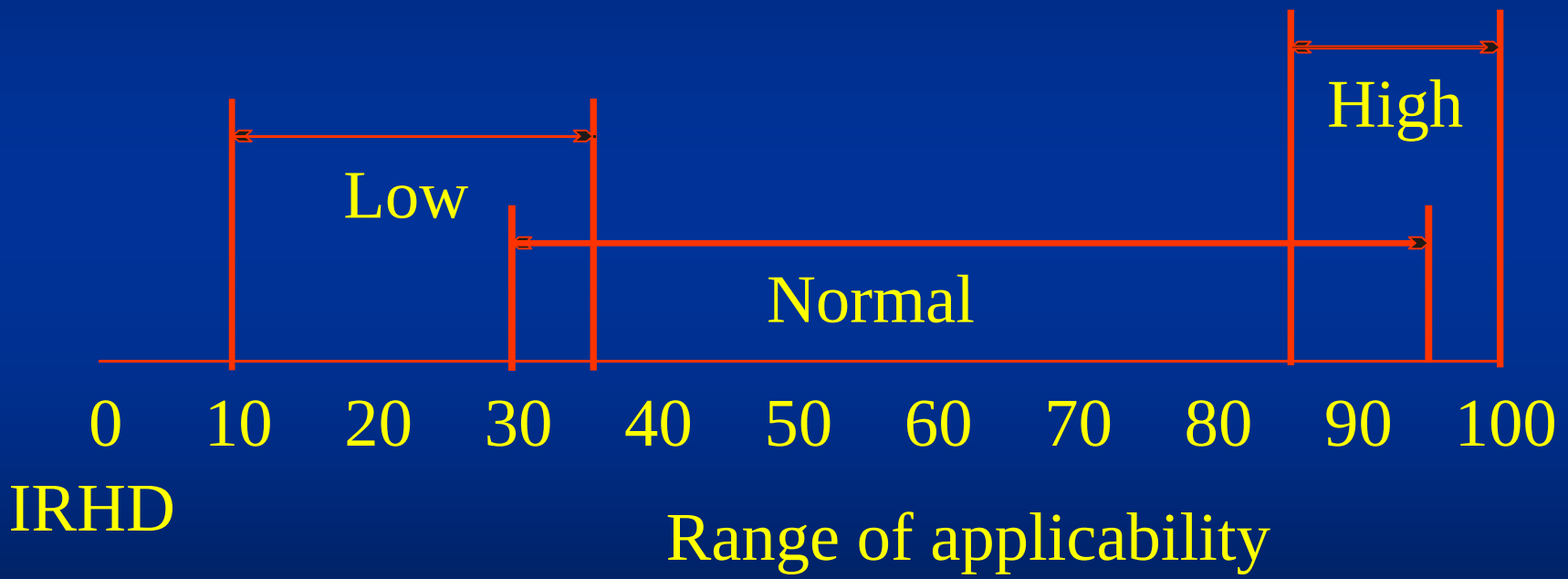
Rubbers: Hardness scale



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Project MPP7.7

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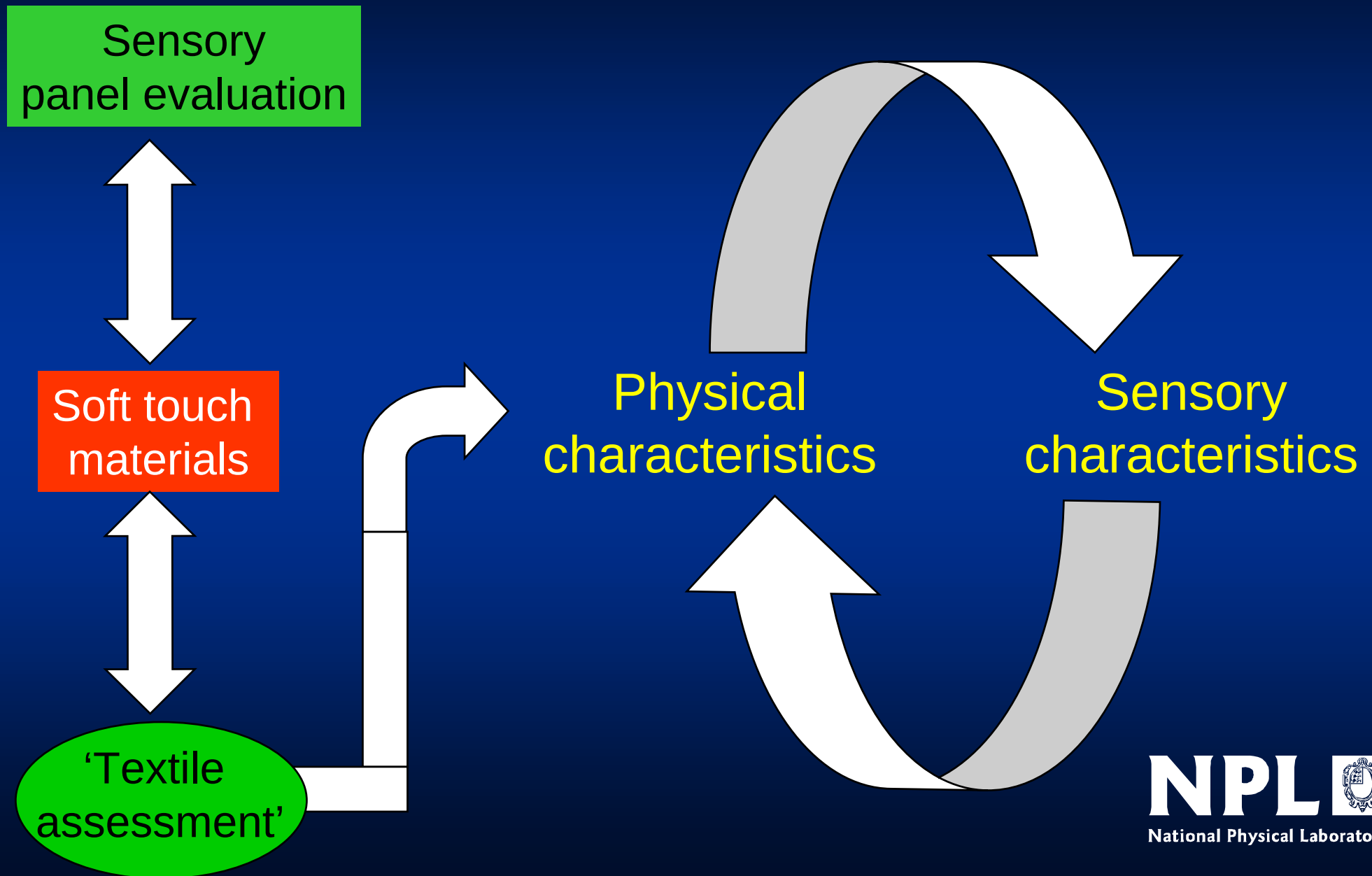
Original plans to link textile evaluation to soft touch



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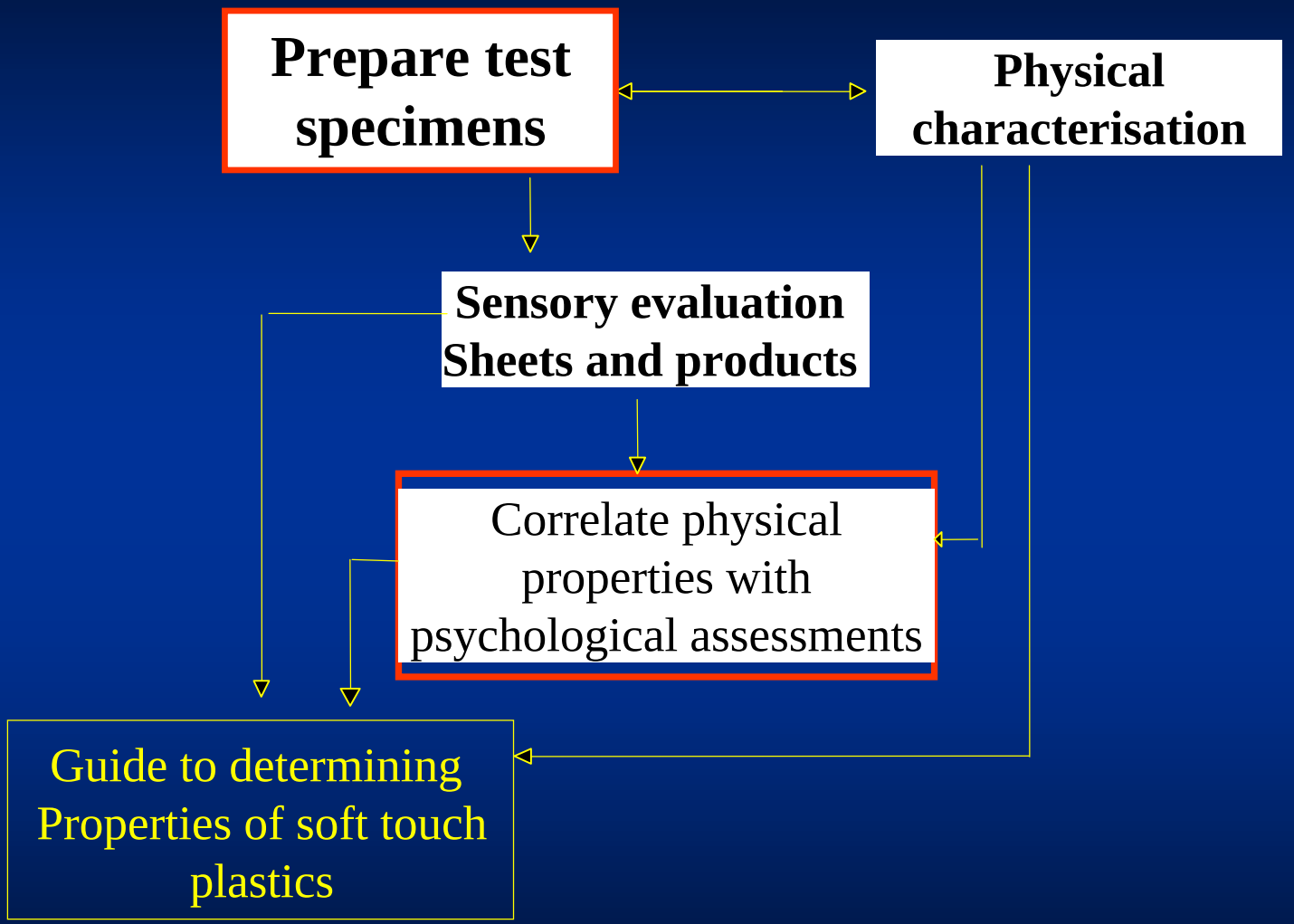
Project overview – Current Status



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KES instrumentation limits

- Sample thickness (<3mm)
- Tensile load (<
- Sample size (20*20cm)
- Surface roughness (<
- Shear load

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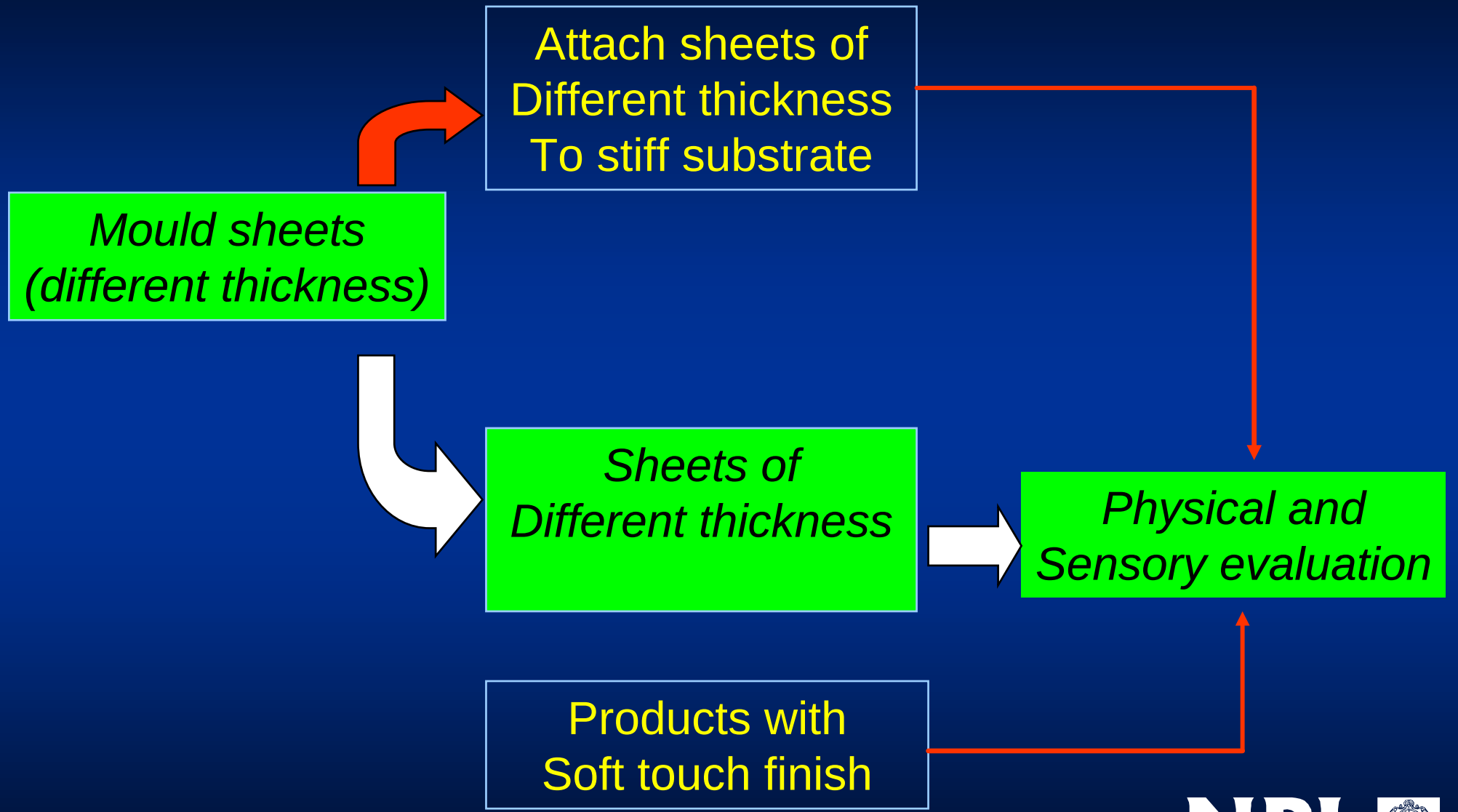
Prepare test specimens



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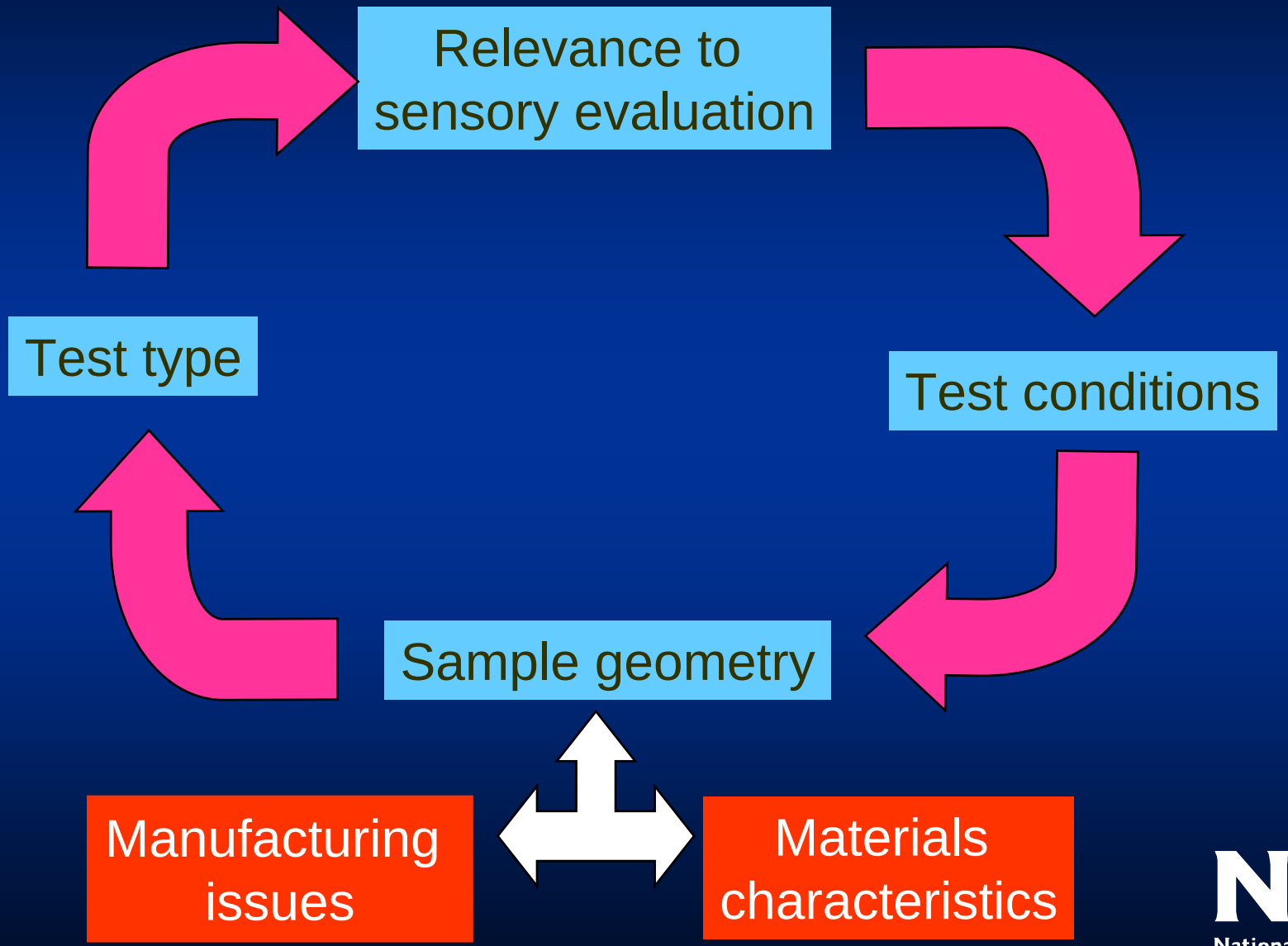
Design of experiments!



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Mechanical test conditions

What loads need to be applied to soft materials to assess them?

- Single finger tip
- Several finger tips
- Palm
- Inside of hand

How does this load depend on the test material?

What is the time dependence of the applied load – stroking?

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Roughness data

Ubm results and gloss

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‘Warm’ to the touch?

‘The q_{max} value (Watts/m^2°C indicates the instantaneous warm/cool feeling sensed when there is initial contact of fabric with the skin surface. A higher value of q_{max} denotes that there is more rapid movement of heat from the body to the fabric surface resulting in a cooler feeling fabric’

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Factors affecting perceived warmth of a material

- Contact time – importance depends on use of material
- Type of interface – ‘interfacial humidity’
- Contact area and pressure
- Size of heat source (e.g. finger, hand, face) compared with sample
- Material surface characteristics - roughness
- Sample thickness
- Thermal properties of sample and underlying substrate
- Sample porosity

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Measurable quantities:Thermal diffusivity

Speed at which heat passes into a material

$$\alpha = \lambda/\rho.C_p$$

λ= thermal conductivity

ρ= sample density

C_p = specific heat capacity

Major factor affecting instantaneous feeling of 'warmth'

Actually depends on sample geometry, ΔT and heat transfer between skin and sample

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Heat capacity data and thermal diffusivity comparison

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KANSEI

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Kansei Engineering Report (visit Dec. 2002)

'Affective design refers to that part of design which is concerned with the interface between the product and the mind'

http://www.faradaypackaging.com/

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Background of Kansei engineering

- Developed by Nagamachi in 1970's
- Extension of human centred design (ISO 13407:1999)
- Strong growth in Japan – Society of Kansei engineers (1998)
- International journal now published
- Kansei engineering integrated part of product development
- Used by major companies: Seiko-Epson, Mazda, Shiseido Co. Ltd (4th largest global manufacturer of cosmetics

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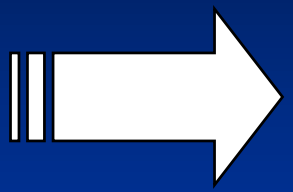
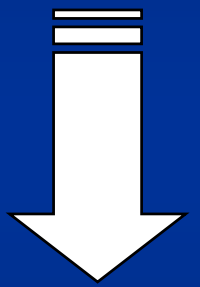
Using Kansei engineering: Adjectives and semantic scales

Source Adjectives
- Consumers
- Designers
- Lifestyle
- Magazines
- Retailers
- Internet search engines
- Mail order catalogues



Group Adjectives (~20)



Score products using 5 or 7 point scales

Use ‘hard’ and ‘not hard’, not ‘hard and soft’ to avoid ambiguity

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Design features and Kansei words

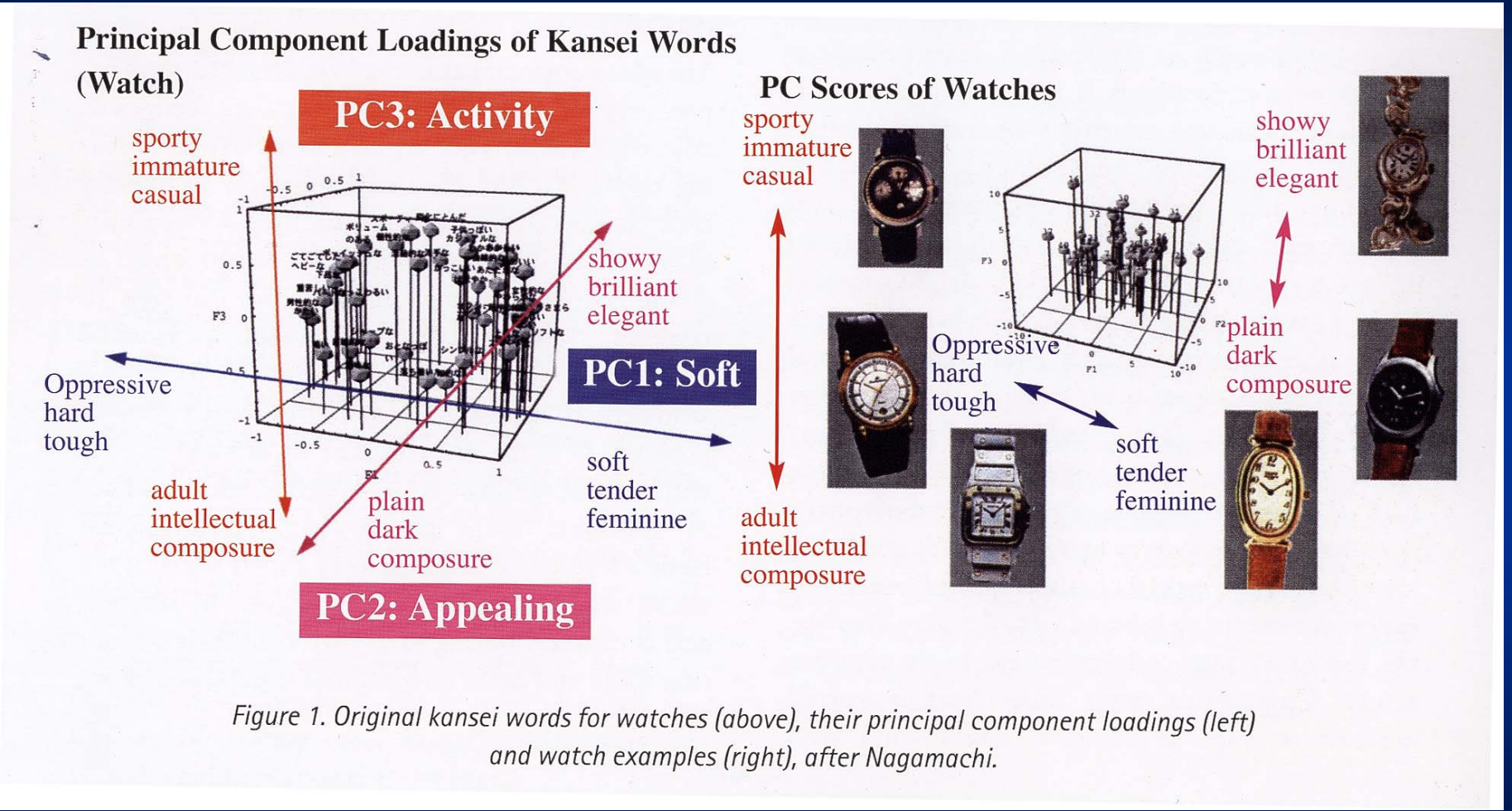

Figure 1. Original kansei words for watches (above), their principal component loadings (left) and watch examples (right), after Nagamachi.

From 'Affective design' Dti report

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Supporting data

- Video recording of body language and facial expressions
- Eye tracking cameras
- Muscular activity (electromyography)
- Sensor instrumented gloves
- Use of data e.g. range of finger size in population, influence of sex, gender and ethnicity to support Kensei vocabularly

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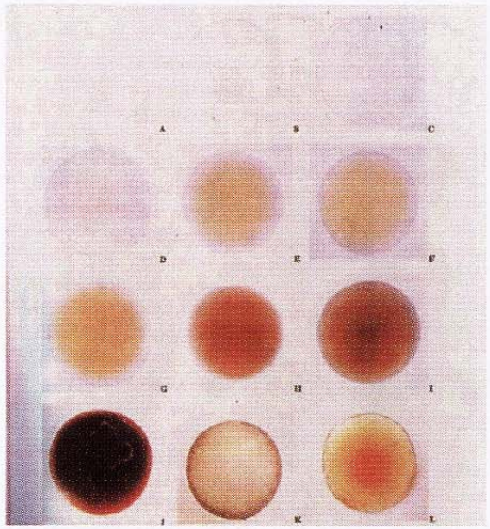
Change in colour perception with age!



6 months	8 years	12 years
25 years	47 years	60 years
70 years	82 years	91 years
Cataract 70 years	Cataract 68 years	Cataract 74 years

Figure 6. Human eye changes with age and associated differences in colour perception, courtesy of Toppan.

From 'Affective design' Dti report

KES of leather

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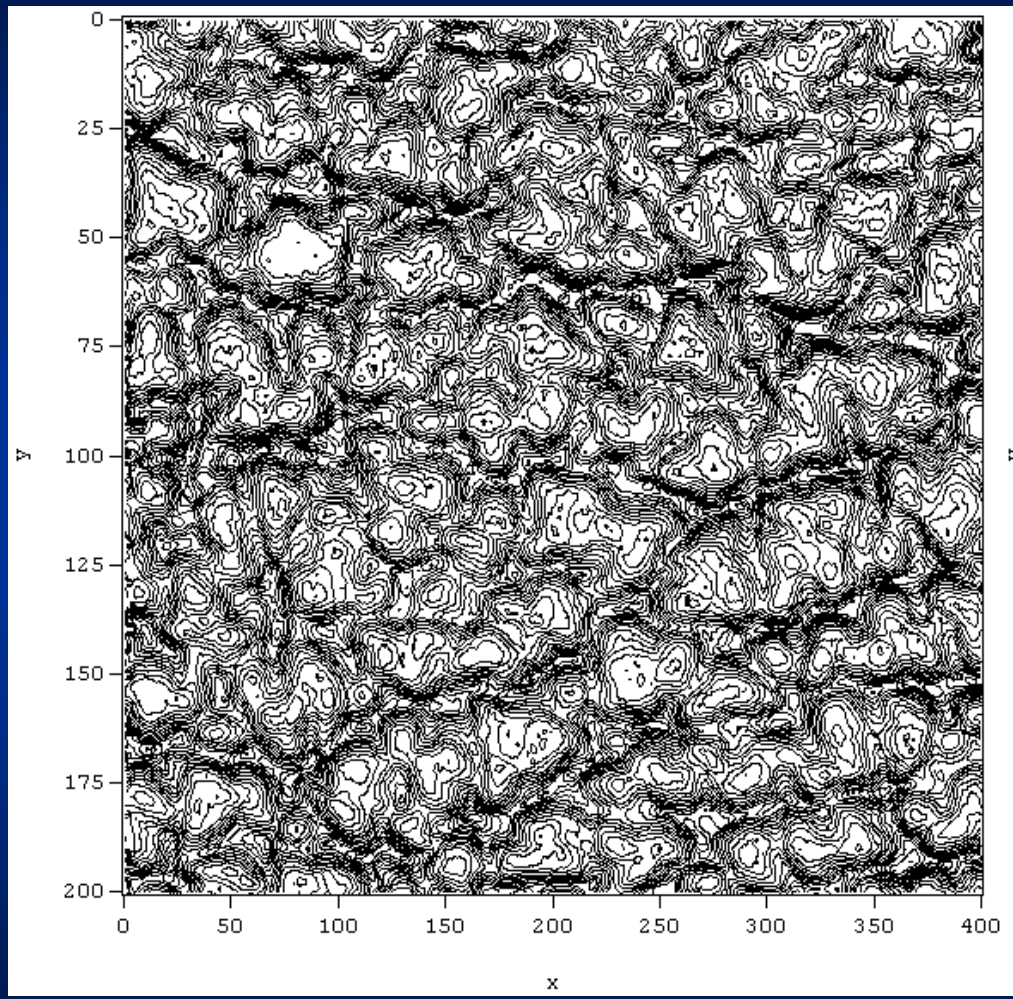
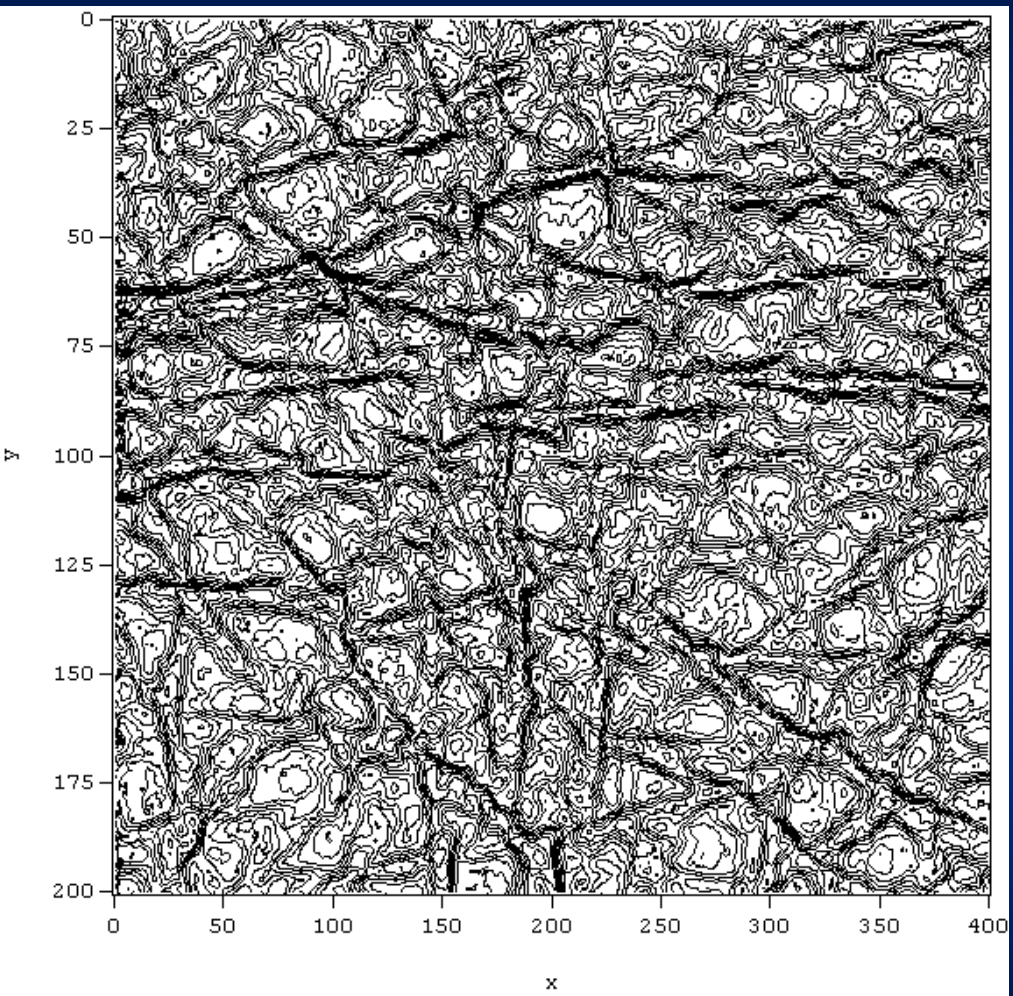
Leather contour maps



Sample C



Sample A

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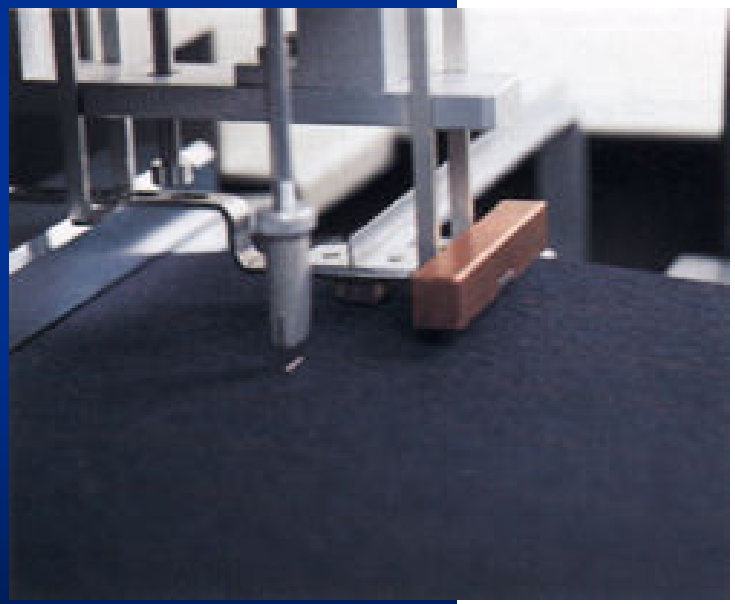
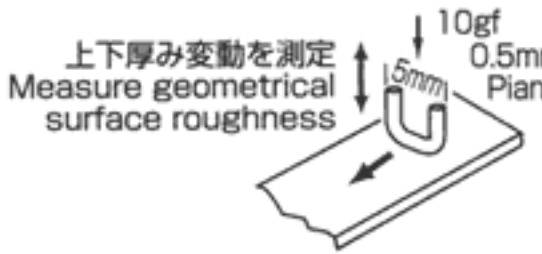
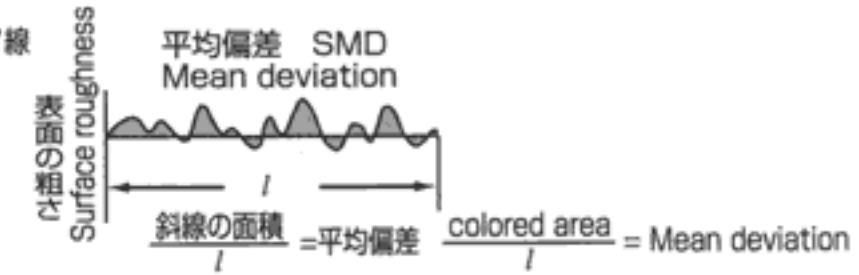
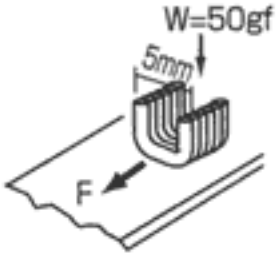
Surface roughness and friction

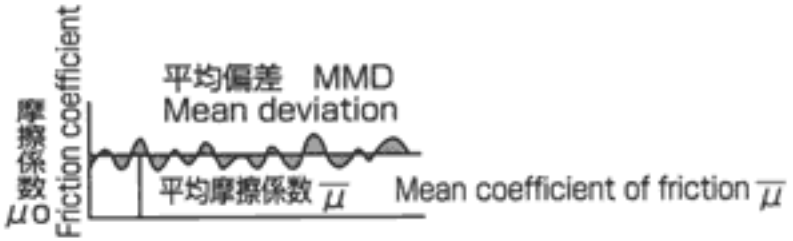


Kesato, Japan







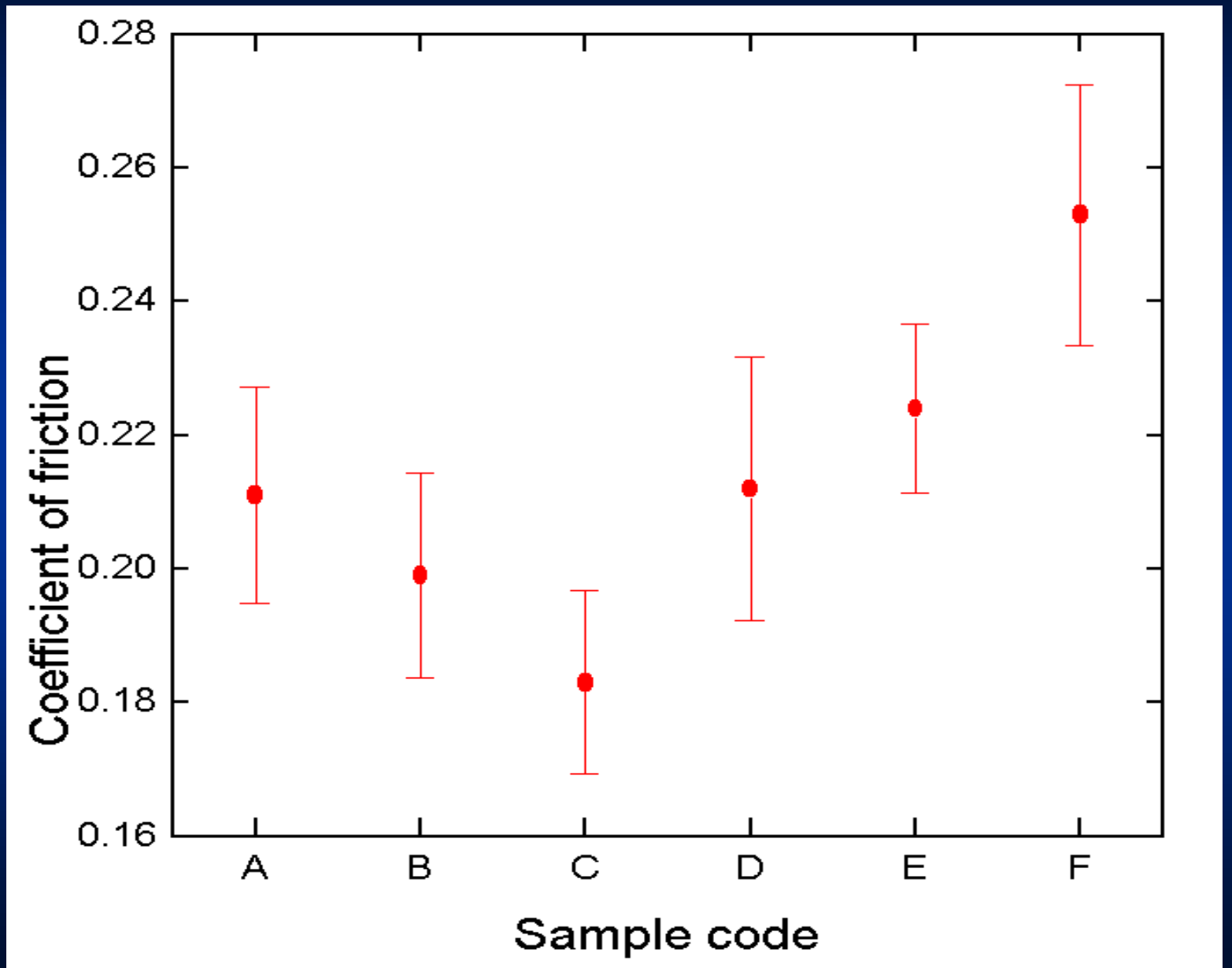


摩擦力Fを測定 $\mu = \frac{F}{W}$

特性値 Property	
平均表面摩擦係数 $\overline{\mu}$	MIU (—)
表面摩擦係数の変動性（平均偏差）	MMD (—)
表面粗さ（平均偏差）	SMD (micron)

表面特性
Frictional property

Coefficient of friction for different leather samples



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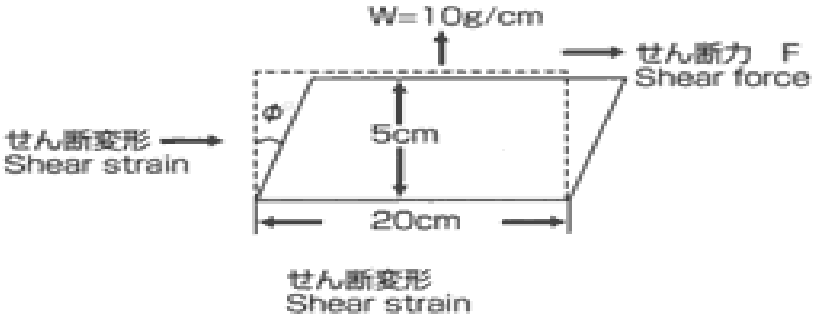
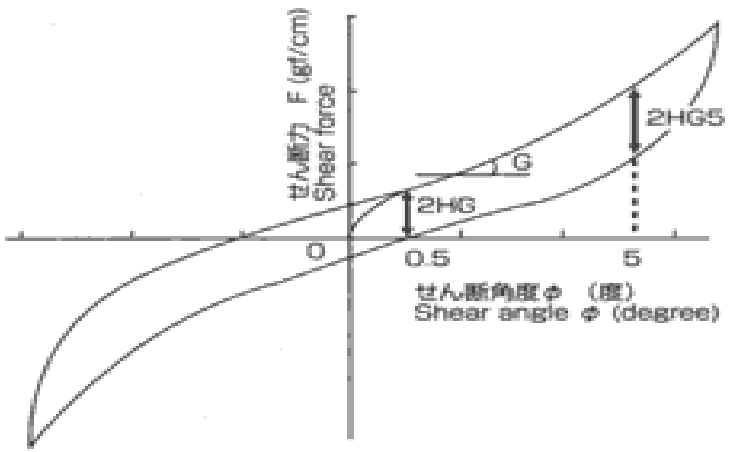
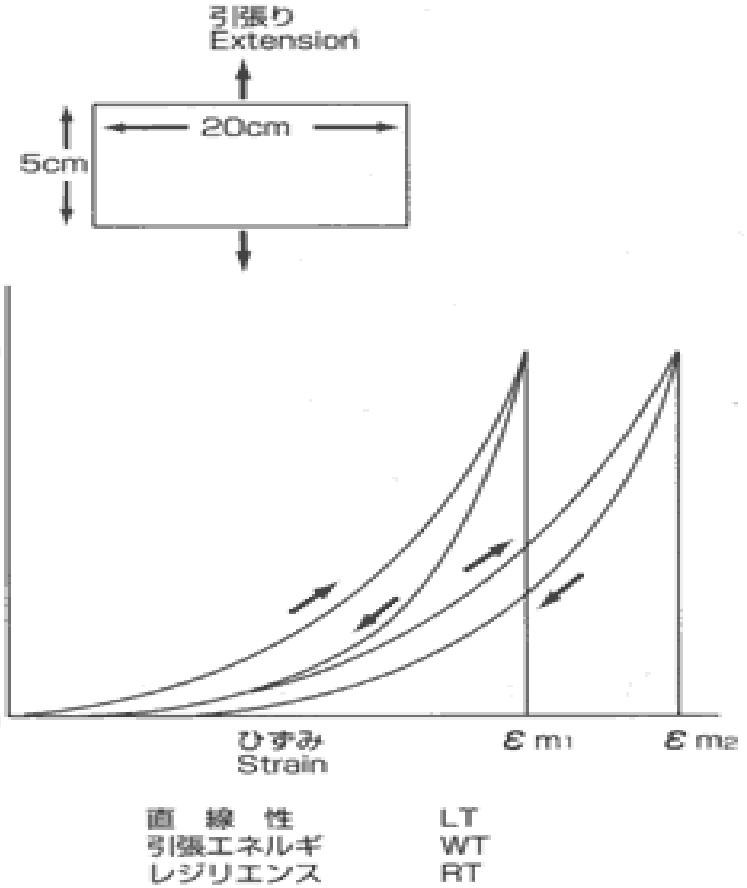
Shear and tensile properties





布1cm当たりのせん断剛さ G(φがgf/cm、度)
せん断ヒステリシス 2HG(gf/cm)
5 せん断ヒステリシス 2HG5(gf/cm)

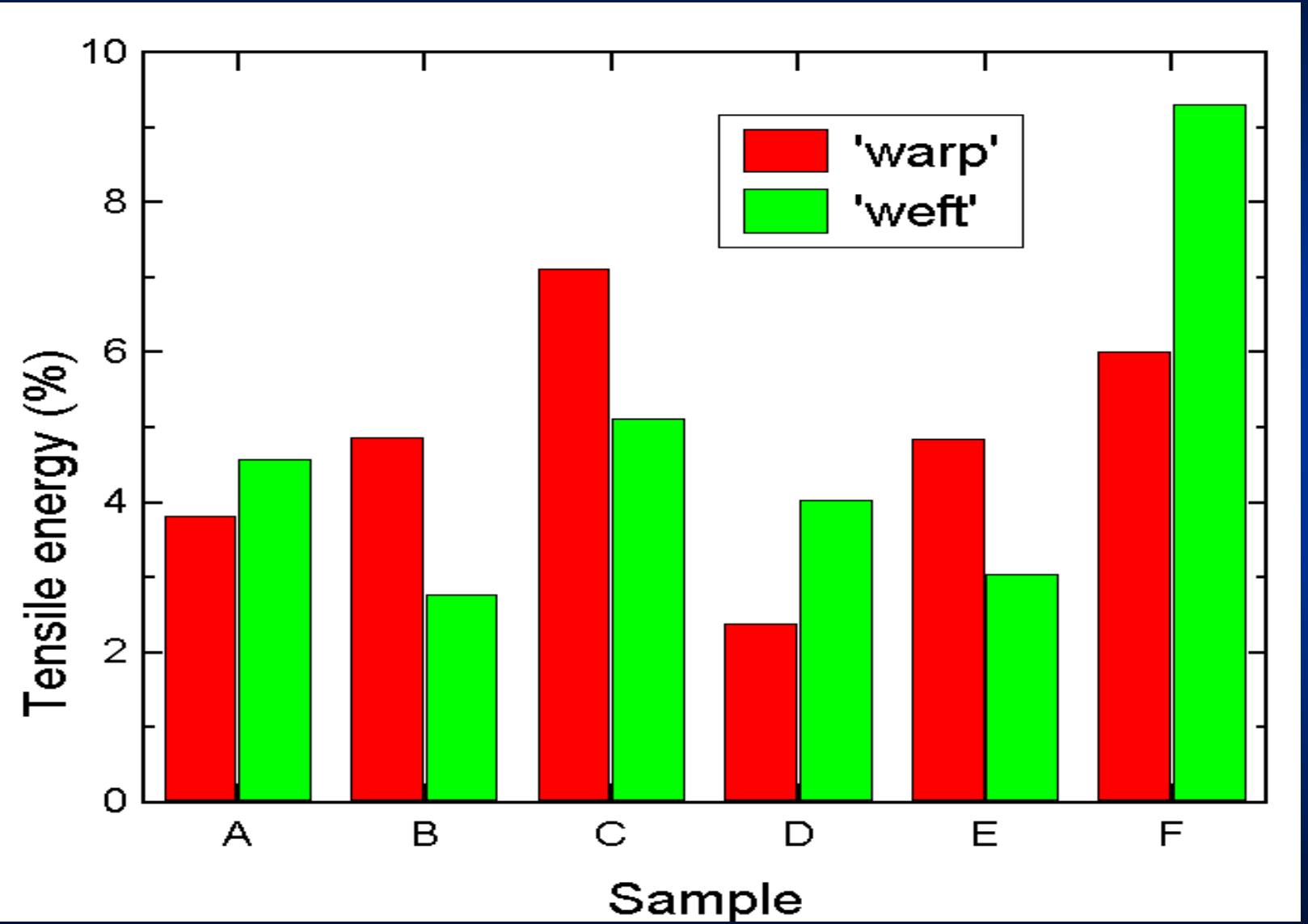
せん断力とせん断角度の関係図
Correlation between shear force and angle



直線性	LT
引張エネルギ	WT
レジリエンス	RT

Kesato, Japan

Tensile deformation



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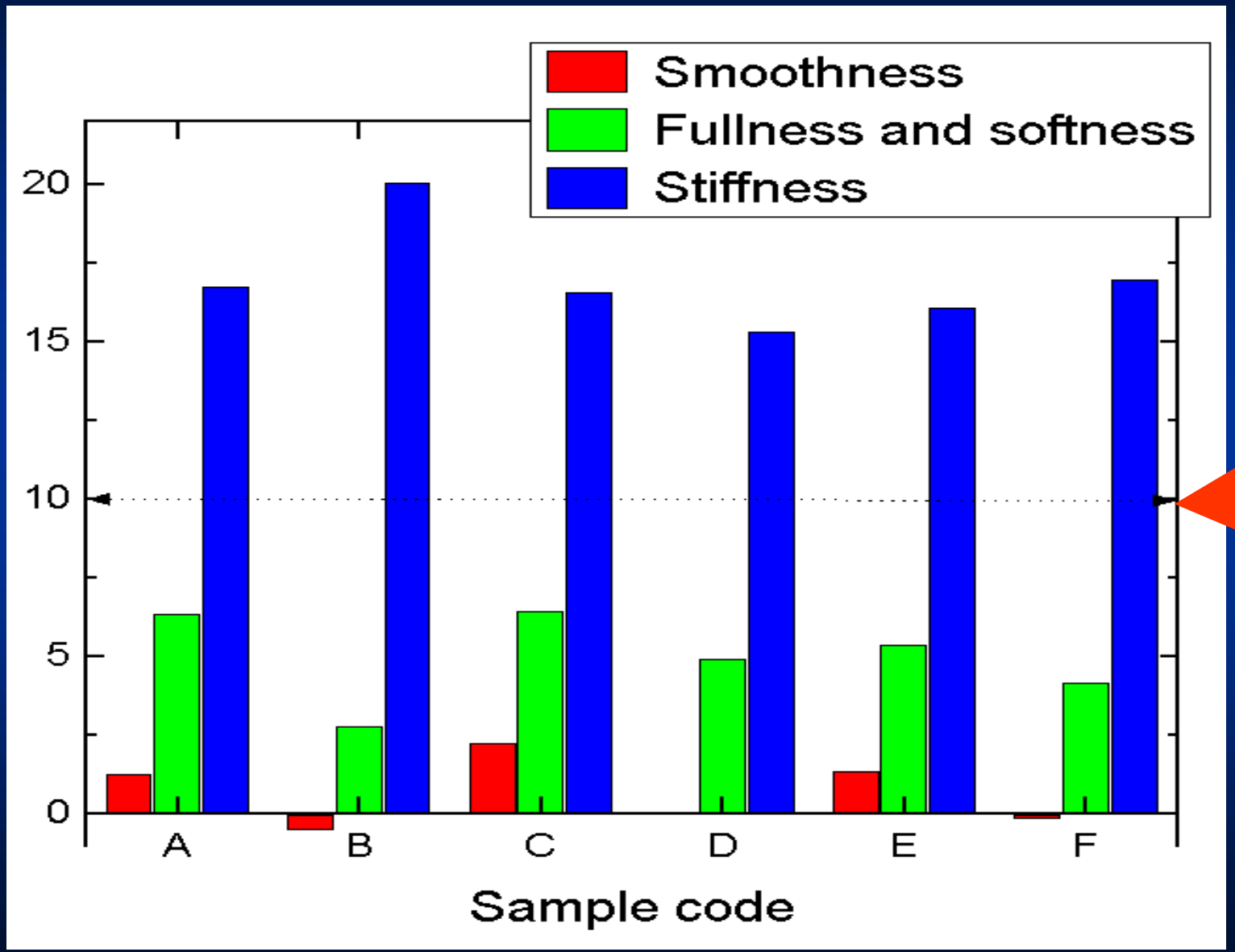
KES sensory evaluation of leather samples



Max stiffness for fabrics

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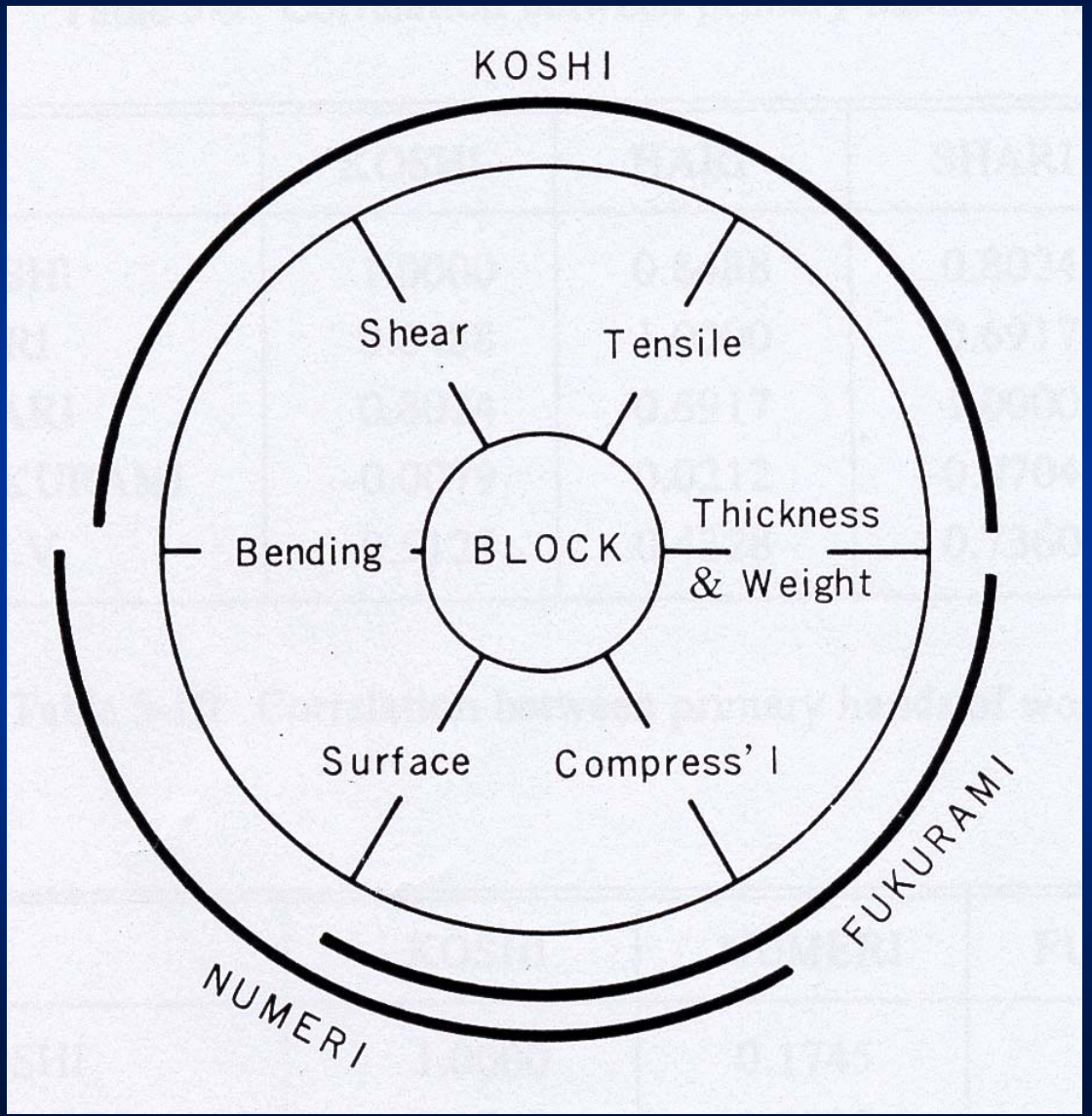
KES sensory descriptors - ‘hands’



Koshi = stiffness (springy feeling)

Numeri = smoothness (feel of cashmere)

Fukurami = fullness and softness – means swelling

From ‘Affective design’ Dti report

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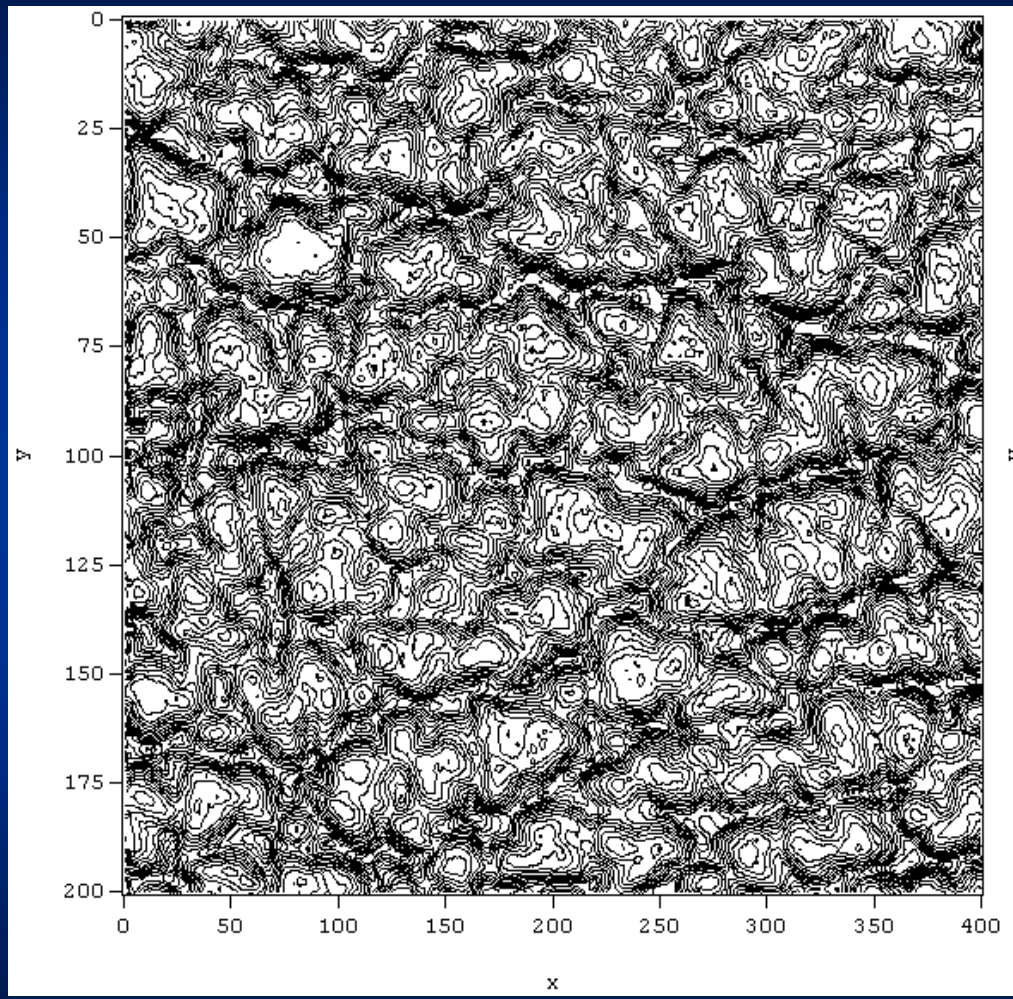
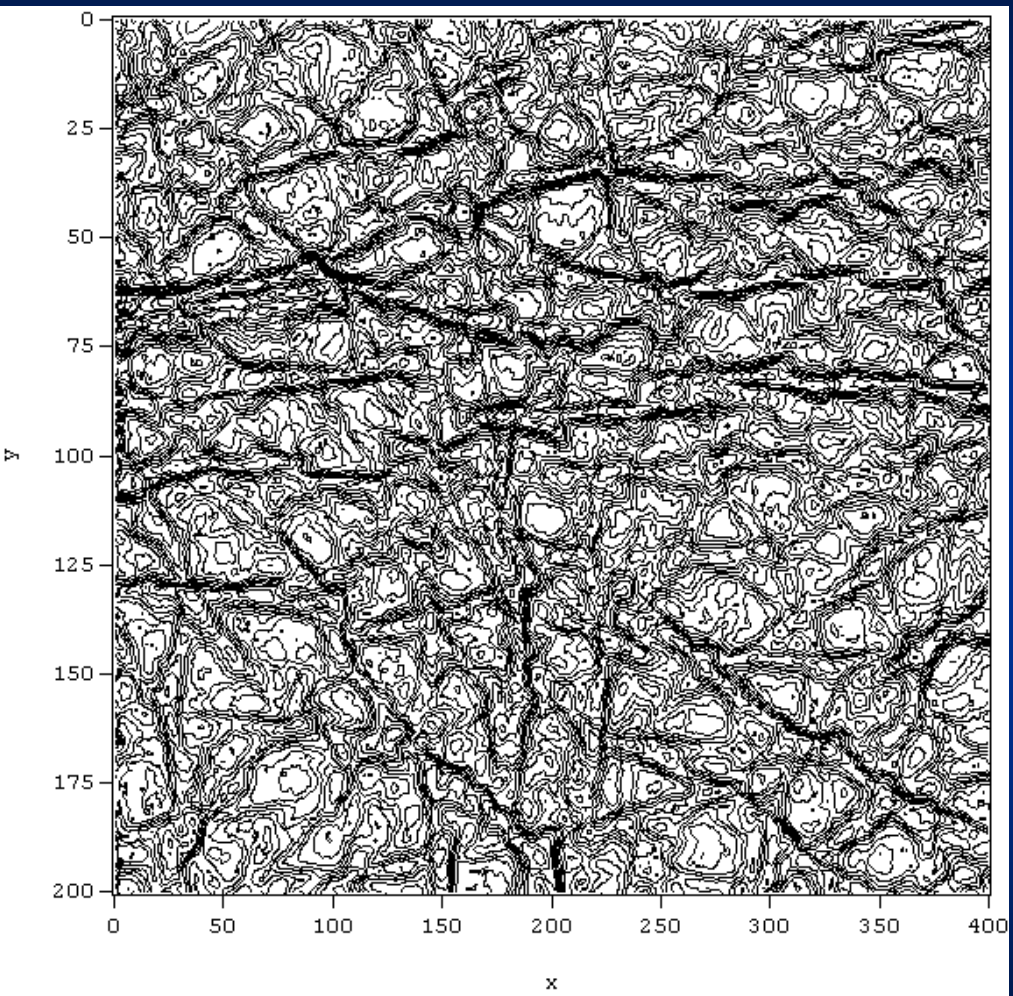
Interpretation of the profile, ‘hardness’ of domains





Sample C

Sample A

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Proposed studio project: soft metrology of leather

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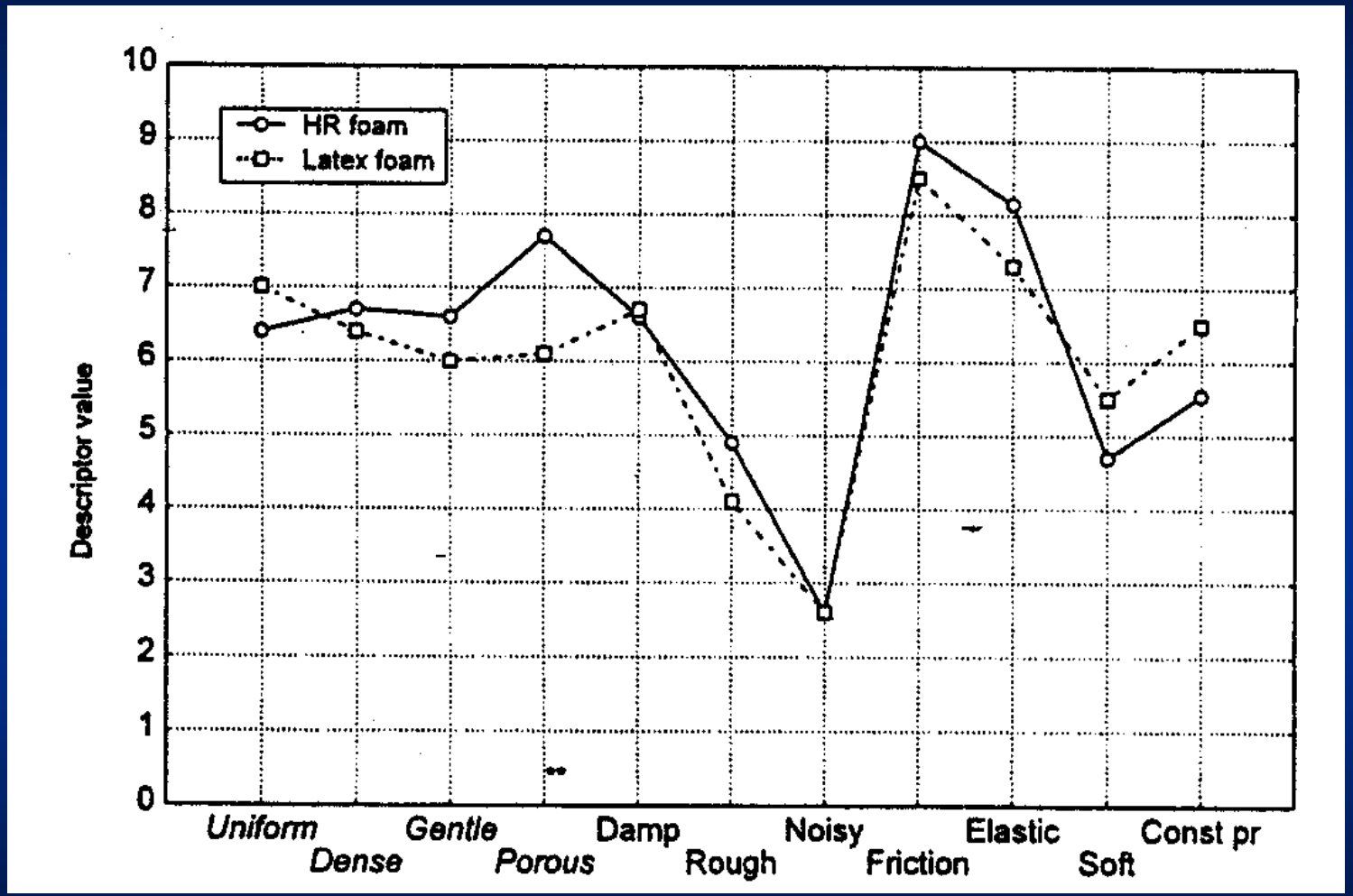
Multivariable assessment: Sensorogram (Foam)



(Shears et al, 1997)

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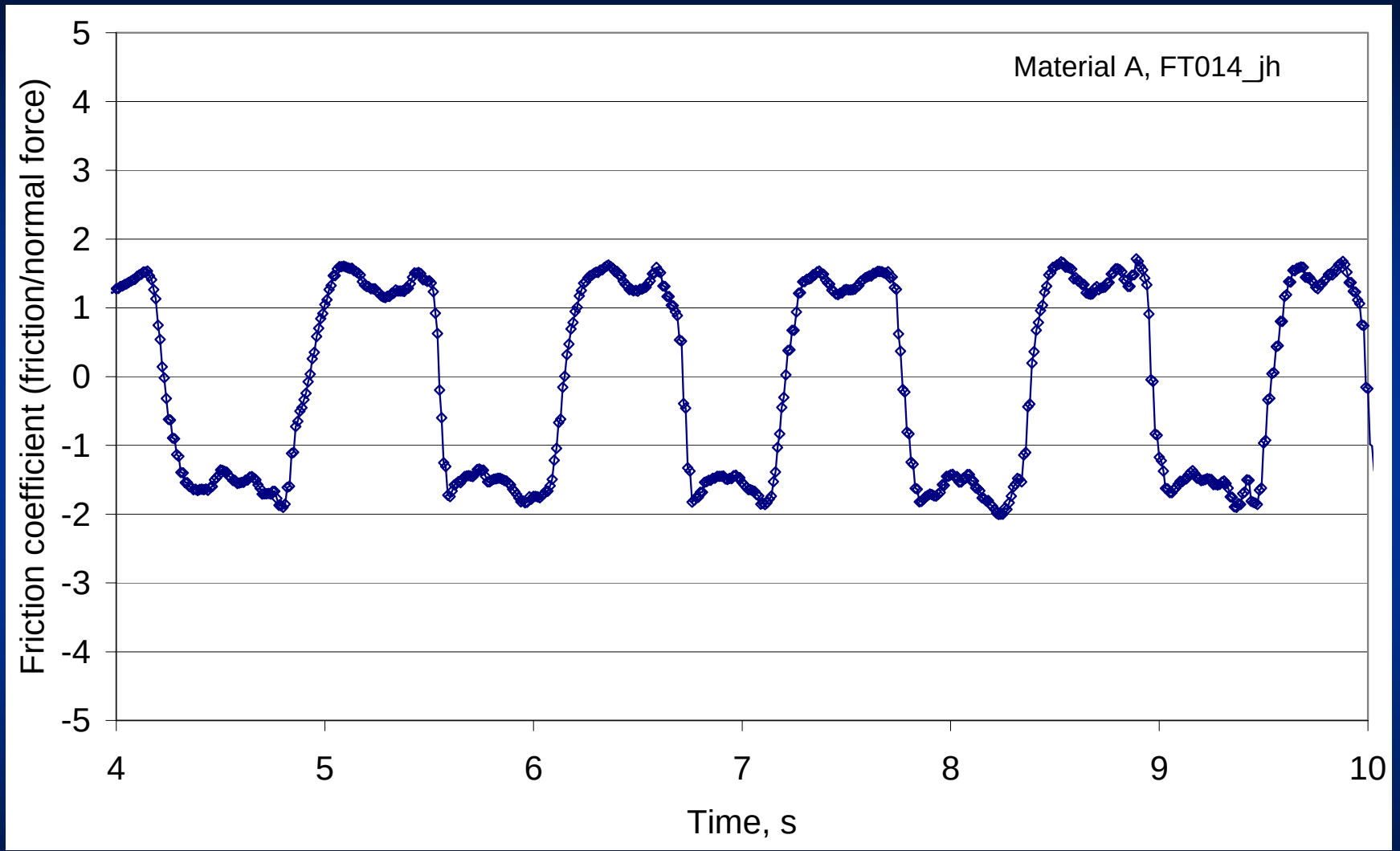
Friction measurements of soft materials



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